Engineering Evaluation/Cost Analysis Report

Elizabeth Mine
South Strafford, Vermont

Final Report

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List of Acronyms

ADL	Arthur D. Little, Inc.
AIME	American Institute of Mining, Metallurgical and Petroleum Engineers
ALD	Anoxic Limestone Drain
AMD	Acid Mine Drainage
AML	Abandoned Mine Lands
APE	Area of Potential Effect
ATSDR	Agency for Toxic Substances and Disease Registry
AVS/SEM	Acid Volatile Sulfide/Simultaneously Extracted Metals
BERA	Baseline Ecological Risk Assessment
BNA	Base Neutral Acids
BOD	Biological Oxygen Demand
CLP	Contract Laboratory Program
COCs	Contaminants of Concern
EBOR	East Branch of the Ompompanoosuc River
EE/CA	Engineering Evaluation/Cost Analysis
EMCAG	Elizabeth Mine Community Advisory Group
EMSG	Elizabeth Mine Study Group
EPA	United States Environmental Protection Agency
ET	Evapotranspiration
gpm	gallons per minute
HHRA	Human Health Risk Assessment
HIs	Hazard Indices
HQs	Hazard Quotients
HRT	hydraulic retention time
IBI	Index of Biotic Integrity
MCLs	Maximum Contaminant Levels
MOA	Memorandum of Agreement
NHPA	National Historic Preservation Act
NPDES	National Pollution Discharge Elimination System
NTCRA	Non Time Critical Removal Action
OSHA	Occupational Safety and Health Administration
PCBs	polychlorinated biphenyls
PRSC	Post-Removal Site Control
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
SAPS	Successive Alkalinity Producing Systems
SHPO	Vermont State Historic Preservation Officer
SMCRA	Surface Mining Control and Reclamation Act
SPAD	Semi-Passive Alkalinity Doser
SRBs	Sulfate Reducing Bioreactors
SVOCs	semivolatile organic compounds
TBC	to-be-considered

TCLP	Toxic Compound Leach Procedure
TDS	total dissolved solids
TOC	total organic carbon
TP-1	Tailings Pile 1
TP-2	Tailings Pile 2
TP-3	Tailings Pile 3
TP-4	Tailings Pile 4
TSS	total suspended solids
USACE	United States Army Corps of Engineers
VHAs	Vermont Health Advisories
VOCs	volatile organic compounds
VTDEC	Vermont Department of Environmental Conservation
VTSWMR	Vermont Solid Waste Management Rules
VTWQS	Vermont Water Quality Standards
WBOR	West Branch of the Ompompanoosuc River
XRD	x-ray diffraction
ZnS	zinc sulfide

INTRODUCTION

This report presents an Engineering Evaluation/Cost Analysis (EE/CA) prepared by Arthur D. Little Inc. for the U.S. Army Corps of Engineers, New England District, (NAE) pursuant to an interagency agreement with the U. S. Environmental Protection Agency (EPA). The EE/CA supports a Non-Time-Critical Removal Action (NTCRA) at the Elizabeth Mine Site in Strafford and Thetford, Vermont. Investigations to date indicate the need for a NTCRA to abate, prevent, minimize, stabilize, mitigate, or eliminate threats to the human health and environment.

The Superfund Law (Comprehensive Environmental Response, Compensation and Liability Act of 1980, CERCLA) and the implementing regulations described in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP 40 C.F.R. 300) describe two types of actions available to EPA when responding to the release of hazardous substances, pollutants, or contaminants into the environment. The two types of cleanup actions are: remedial actions and removal actions. A remedial action, the standard Superfund cleanup, is not initiated until after the completion of the comprehensive study known as the remedial investigation and feasibility study (RI/FS). A removal action can proceed more quickly than a remedial action.

Section 300.415(b)(4)(i) of the NCP requires the completion of an EE/CA for all NTCRAs. The objective of an EE/CA is to:

- Identify removal action objectives for the protection of human health and the environment,
- Identify NTCRA cleanup alternatives, and
- Assess the effectiveness, implementability, and cost of the alternatives.

Meaning of the term "Non-Time-Critical Removal Action" (NTCRA)

Based on the type of situation, the urgency and the threat of the release or potential release, and the time frame in which the action must start, EPA categorizes removal actions in three ways:

1. Emergency,
2. Time-Critical, or
3. Non-Time-Critical.

Emergency and Time–Critical removal actions respond to releases requiring action within 6 months; Non–Time–Critical removal actions (NTCRA) respond to releases requiring action that can start more than 6 months after a determination for the need to respond.

The range of actions planned at Elizabeth Mine do not include actual removal of material but rather combining and covering/capping of tailings and water treatment. Nevertheless, under the Superfund program, these actions are referred to as "removal actions".

Reference: EPA, 1993, *Guidance on Conducting Non–Time–Critical Removal Actions Under CERCLA*, EPA 540-R-93-057, August

Figure ES-1 presents the schedule for the Elizabeth Mine NTCRA.

Section 1: Introduction

Site Description

The Elizabeth Mine is located in the towns of Strafford and Thetford in east-central Vermont, approximately 1.9 miles southeast of the village of South

Strafford, on the eastern flank of Copperas Hill. It is approximately 15 miles north of White River Junction and 9 miles west of the Connecticut River (See Figure ES-2 for Site Location Map). Four areas have been identified as potential sources of contamination (See Figure ES-4 for Site Contamination Map):

Three areas of waste rock, tailings, and heap leach piles:

- TP-1 a 30 acre tailing pile;
- TP-2 a 5 acre tailing pile; and
- TP-3 a 12 acre area of heap leaching piles and waste rock.

Two areas of excavated bedrock:

- North Open Cut; and
- South Open Cut.

The underground workings (shafts and adits) that extend for almost one mile northward under the West Branch of the Ompompanoosuc River (WBOR).

A small area of tailings and associated shafts and cuts near the South Open Cut (referred to as the South Mine).

The three areas of waste rock, tailings, and heap leach piles (TP-1, TP-2, and TP-3) as well as the North Open Cut are located within the Copperas Brook drainage basin. The Copperas Brook watershed drains into the WBOR, approximately six miles upstream from its confluence with the Ompompanoosuc River, near the Union Village Dam. The Ompompanoosuc River empties into the Connecticut River approximately three miles downstream of the Union Village Dam.

The South Open Cut and the South Mine are located within the Lord Brook watershed. These two source areas discharge to a small seasonal stream that flows into Lord Brook. Lord Brook runs along the eastern side of Gove Hill until joining with the WBOR just west of the Route 132 bridge in Thetford.

The water collected within the one mile of underground mine workings discharges at a location known as the "airshaft". The water from the airshaft flows down a short drainage into the WBOR about 0.5 miles upstream of the Copperas Brook - WBOR confluence.

Site History

Studies by the Vermont Agency of Natural Resources (VTANR) during the 1970's and the U.S. Army Corps of Engineers (USACE) in the 1980's identified the Elizabeth Mine as a source of pollution to the WBOR.

In 1999, the VTANR requested EPA to conduct an assessment of the Elizabeth Mine to determine if a removal action would be an appropriate early cleanup. EPA performed an initial evaluation and concurred with the VTANR assessment that there was an obvious source of contamination at the Site that could be addressed as an early action using the EPA Non-Time-Critical Removal Action (NTCRA). EPA signed an Approval Memorandum in February 2000 authorizing the preparation of an Engineering Evaluation and Cost Analysis (EE/CA) in support of the early cleanup (NTCRA). To assure the complete characterization of the Site and all potential sources of contamination, the State of Vermont requested that EPA propose the Site for listing on the National Priorities List (NPL) in December 2000. The Elizabeth Mine was placed on the NPL in June 2001.

The industrial history of the Elizabeth Mine began with the discovery of a massive sulfide ore body along a ridge located southeast of South Strafford village in 1793. The mine was initially worked for the sulfide mineral pyrrhotite to manufacture copperas. Copperas is a crystalline green hydrous iron sulfate that has been used for a variety of purposes including: production of sulfuric acid; a disinfectant and sheep dip; astringent medicine; to blacken and color leather; and as a drier in ground pigment manufacturing. Major production of Copperas began in 1810 and ended in the 1880s. In 1830, Strafford Copper Works was formed to extract copper from the mine. During the early mining operations, copper was smelted on-site.

Underground mining began in the early to mid-1800s. The mine was worked intermittently for copper from 1830 until 1930. In 1942, the mine reopened in response to World War II. Most of the underground copper mining occurred between 1942 and the mine's final closure in 1958.

The copperas production area includes 12 acres at the top of the Copperas Brook watershed adjacent to the North Open Cut. This area contains colorful piles of variably pyrolyzed sulfide ore that are part of the "heap leach" piles from the copperas production. Some of the heap leach piles are overlain by waste rock from some of the earliest copper mining at the Site. This area is known as TP-3.

The tailings in areas designated as TP-1 and TP-2 were generated through the milling of sulfide ores between 1942 and 1958. A sulfide flotation mill was constructed during this period, where the ore was refined and the resulting concentrate was shipped to off-site smelters. The remaining material was pumped to settling ponds, resulting in the formation of the tailings piles. Today, an orange iron-oxide rich "rind" covers the surface of TP-1 and TP-2 to a depth of one to two feet below the tailings surface. Below this oxidized cap, a uniform layer of black sulfide-rich anoxic tailings extends to the base of each pile.

Historic Significance of the Elizabeth Mine

The Elizabeth Mine is a historic resource that embodies the distinctive landscape, engineering, and architectural resources that are characteristic of an early nineteenth- to mid-twentieth-century American metal mining and processing site. It constitutes one of the largest and most intact historic mining sites in New England and includes the only intact cluster of hard-rock mining buildings in the region.

The Elizabeth Mine was the site of a major nineteenth century U.S. copperas manufacturing plant and is associated with successful patents for copperas production. It is also associated with a number of significant commercial, scientific, and political figures, including Isaac Tyson, Jr., a Baltimore, Maryland-based chemical and mining figure who was recently inducted into the American Institute of Mining, Metallurgical and Petroleum Engineers' (AIME) Mining Hall of Fame. EPA has determined the Elizabeth Mine Site to be eligible for listing on the National Register of Historic Places.

Streamlined Risk Evaluation

An evaluation of the data was performed to assess the impact of the Elizabeth Mine of the environment. The result of that assessment is summarized below.

The biological community (benthic organisms[1] and fish) in Copperas Brook, the upper reach of Lord Brook below the South Open Cut, and in the Mixing Zone of the WBOR below Copperas Brook is severely affected by mine-related contamination. The biological community appears to recover to conditions similar to upstream (Reference) locations at some point before the confluence of the WBOR with the Ompompanoosuc River above Union Village Dam, although metal concentrations in algae remain high below the dam. Surface water and sediment in Copperas Brook, the first section (upstream) of the Mixing Zone, and the Air Vent are highly toxic to aquatic organisms, such that survival of aquatic receptors in this area is not likely. These toxic effects are not present below the Mixing Zone.

Collectively, various lines of evidence suggest that EPA Sample Location 29, situated downstream from Union Village Dam, represents the best estimate for the location where the WBOR achieves Vermont Water Quality Criteria for both surface water and biological measures. The distance from the Copperas Brook confluence to EPA Sample Location 29 is approximately 6 miles.

[1] Benthic organisms are small, riverine bottom-dwelling animals without backbones that serve as a food source for higher level organisms such as fish.

In addition, chemical evidence from sediment sampling and recent findings made by VTANR indicate the potential for concentrations above numerical VTWQS that result in adverse effects to the benthic community downstream to EPA Sample Location 44, about 5 miles.

Since all of the lines of evidence show that Copperas Brook and the Mixing Zone are the most severely impacted, it can be inferred that TP-1, TP-2, and TP-3, which are the contaminant sources located within the Copperas Brook drainage, are the cause of the impacts to the WBOR. These impacts firmly support the need for an early cleanup action (NTCRA) to address the principal sources of acid mine drainage (AMD).

An assessment of potential impacts to human health was also performed. Contamination from the site has adversely impacted one residential water supply. This well is no longer in use and the residents have re-located. The water of the remaining residential wells in the area were sampled and found to meet federal and state primary drinking water standards.

Section 2: Identification of Removal Action Scope and Objectives

The EE/CA presents the applicable or relevant and appropriate regulations (ARARs) that would apply to the cleanup action. The EE/CA also identifies that an exemption from the statutory limit of 12 months and $2 million dollar for a removal action. This exemption is justified since the cleanup actions contemplated in the EE/CA would be consistent with the final remedial action taken at the Site. Key ARARs that have been identified for the cleanup action include:

- Vermont Solid Waste Management Regulations;
- National Historic Preservation Act;
- Clean Water Act; and
- VT Water Quality Standards.

The EE/CA identified several key ARAR issues that require public comment:

- Unavoidable impacts to wetlands and floodplains;
- Unavoidable impacts to historic resources eligible for the National Register of Historic Places;
- Findings with respect to the Vermont Solid Waste Management Rules to allow TP-3 to remain uncovered and for greater design flexibility with respect to the cover system and slopes of TP-1 and TP-2.

Section 3: Development of Removal Action Alternatives

Removal Action Objectives

The impacts of AMD from the Site support the need for an early cleanup action (NTCRA) to address the principal sources of AMD.

The overall goal of the NTCRA is to restore the WBOR to Vermont Water Quality Standards (VTWQS). Some numerical VTWQS may not be achieved as a result of the naturally occurring levels of certain metals in the watershed. The NTCRA focuses on the following objectives:

- Achieve VT Water Quality Standards (chemical and biological) as well as other applicable standards in the West Branch of the Ompompanoosuc River by preventing or minimizing discharge of water with mine-related metals contamination to Copperas Brook and the WBOR;

- Minimize the erosion and transport of tailings or contaminated soil into the surface waters of Copperas Brook and the West Branch of the Ompompanoosuc River;

- Evaluate stability of waste piles (tailings, waste rock, and leach piles) and modify slope configurations (re-grading, covering or buttressing) as necessary to provide for an acceptable level of long-term stability;

- Consider measures to minimize and avoid an adverse effect on historic resources at the Site, as required by the National Historic Preservation Act; and

- Comply with all applicable federal and state regulations.

In addition to protection of human health, Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota. "Ecological Risk Assessment and Risk Management Principles for Superfund Sites", OSWER Directive 9285.7-28P, October 1999

Removal Action Alternatives
EPA evaluated numerous potential cleanup technologies in developing the EE/CA. An initial screening of technologies and alternatives for the Site is documented in the E*nvironmental Response Alternative Analysis Report, April 2001*. Public feedback from this report resulted in the development of five alternatives to be evaluated in detail in the EE/CA.

All Alternatives include these baseline items:

- Preservation of all or a portion of TP-3 (up to 100%, exact amount to be determined)
- Diversion of surface water away from TP-1 and TP-2
- Collection of storm water runoff and drainage from TP-3 and treatment with passive systems
- Collection of drainage from toe of TP-1 and treatment with passive systems
- Stabilization of the steep slope areas of TP-1 and TP-2, as necessary, and
- Backfilling/stabilization of decant pipe

Alternative 2B (Geomembrane Cap with TP-2 removal)

- Consolidation of TP-2 into the footprint of TP-1
- Placement of an infiltration barrier cover system over consolidated TP-1
- Placement of soil and a drainage layer to protect the infiltration barrier and promote vegetation (grass)

Alternative 2C (Geomembrane Cap)

- Consolidation of a small portion of TP-2 onto TP-1
- Minor re-shaping of TP-1 and TP-2
- Placement of an infiltration barrier cover system over TP-1 and TP-2
- Placement of soil and a drainage layer to protect the infiltration barrier and promote vegetation (grass)

Alternative 3B (Evapotranspiration Soil Cover)

- Consolidation of a small portion of TP-2 onto TP-1
- Minor re-shaping of TP-1/TP-2
- Placement of a 42 inch thick soil cover over TP-1 and TP-2 to reduce infiltration by means of evaporation and plant use (not an infiltration barrier)

Alternative 3C (Minimal Soil Cover)

- Consolidation of a small portion of TP-2 onto TP-1
- Minor re-shaping of TP-1/TP-2
- Placement of the least amount of soil over the surface of TP-1 and TP-2 that will support long-term vegetation, assumed to be 6 inches (not an infiltration barrier)

Alternative 3D (Hardpan Barrier Layer)

- Consolidation of a small portion of TP-2 onto TP-1
- Minor re-shaping of TP-1/TP-2
- Mixture of lime and/or crushed limestone into the tailings to form a chemical cap to encapsulate TP-1 and TP-2

- Placement of 18 inches of soil to promote a long-term vegetative cover
- Placement of a drainage net beneath the soil to prevent ponding of water above the hardpan layer

Section 4: Comparative Analysis of Removal Action Alternatives

Section 4 of the EE/CA contains a detailed evaluation of each alternative against the three NTCRA criteria: Effectiveness, Implementability, and Cost. Section 5 of the EE/CA compares each alternative against each other based on these criteria. Figure ES-3 presents a summary of the cover systems for the five alternatives. The relative advantages and disadvantages of each alternative are discussed with respect to the following criteria:

1. Effectiveness

   – Overall protection of human health and the environment
   – Compliance with ARARs and other criteria, advisories, and guidance
   – Long-term effectiveness and permanence
   – Reduction in toxicity, mobility, or volume through treatment
   – Short-term effectiveness

2. Implementability

   – Technical feasibility
   – Administrative feasibility
   – Availability of services and materials
   – State and community acceptance

3. Cost

The Cost criterion includes both direct and indirect capital costs.

The State and Community Acceptance criteria will be modified following the public comment period to reflect issues and concerns that arise through discussions with the Elizabeth Mine Community Advisory Group (EMCAG) and the public.

4.1 Effectiveness

4.1.1 Overall Protection of Human Health and the Environment

The five alternatives all offer similar levels of protection of human health and the environment. For TP-3, each alternative has identical performance. For TP-1 and TP-2, the major differences are as follows:

- The thin soil cover component of Alternative 3C is more likely to allow exposure of the tailings as a result of erosion than the covers described for alternatives 2B, 2C, 3B, and 3D;
- The thin soil cover component of Alternative 3C may not be able to sustain a healthy vegetated cover due to acid creep;
- The long-term effectiveness of the Alternative 3D hardpan cap is not known; and
- Alternatives 2B and 2C would result in the least amount of infiltration into the tailings of TP-1 and TP-2. Alternatives 3B and 3D would greatly reduce infiltration while Alternative 3C would have the lowest level of infiltration reduction

(allow the greatest amount of water into the tailings).

The geomembrane cap that is a component of Alternatives 2B and 2C has a proven record of performance. The cover system included in Alternatives 2B and 2C is a tiered system that significantly limits the infiltration of water and oxygen into the tailings. First, the cover system would be designed to have a final surface grade to promote run-off as opposed to allowing infiltration. Second, the natural soil and vegetation component of the cover stores water that is then recycled into the atmosphere through the process of evaporation and transpiration. Third, the drainage layer within the cover provides a high capacity system for removing water that may flow past the first two components. This water is channeled to outlets in the cover system to prevent any long-term storage of water above the geomembrane. Fourth, a geomembrane prevents further water and oxygen migration by acting as seal or barrier to water and air flow. The geomembrane is a continuous sheet of plastic that essentially prevents water from seeping into the tailings. Finally, if determined necessary to assure long-term performance beyond the life expectancy of a geomembrane (could be hundreds of years), a second barrier of a natural material can be included to seal any holes or cracks that may develop in the geomembrane over time. This secondary layer would further prevent the inflow of water and oxygen into the tailings. Either a low permeability soil layer or a geosynthetic clay liner can be used as the second barrier layer. This system of natural and engineering components should eliminate all infiltration of water and oxygen into the tailings from the surface.

The soil cover components of Alternatives 3B, 3C, and 3D also perform the first two functions (surface water drainage and evapotranspiration) described above. Alternative 3C does not have any additional measures to reduce surface infiltration, whereas, Alternative 3D includes the drainage layer component and a single barrier layer (hardpan) to further limit infiltration. Alternative 3B attempts to maximize the use of natural soil properties (storage and evapotranspiration) by increasing the thickness of the soil layer, as opposed to installing a barrier layer. The other aspects of these alternatives, relative to overall protection of human health and the environment, are the same.

4.1.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

All alternatives will have the same level of impact to wetlands, stream channels, and floodplains. These impacts are unavoidable and will be subject to mitigation. A variance/waiver of the VT Solid Waste Management Rules (VTSWMR) is included in the EE/CA. To allow for the preservation of TP-3 and flexibility with respect to the design of the cover system for TP-1 and TP-2, the following alternative measures to the specific criteria in the VTSWMR are being accepted by EPA:

- The design of the cleanup will determine the appropriate surface and slope grades at the Site as opposed to the minimum grade of 5% and the maximum grade of 33% specified in the

VTSWMR. Performance objectives for the grading will be to: minimize ponding on the barrier layer and promote run-off; minimize erosion; minimize AMD generation; and optimize slope steepness in the interest of historic preservation;

- Final closure of exposed waste rock and heap leach piles would not be required for TP-3. EPA would design and construct a collection and treatment system to address the run-off from TP-3. The change is dependent upon VTANR accepting the responsibility for the maintenance of the treatment system; and
- **C**leanup alternatives will not be required to include an infiltration barrier on the slopes of TP-1 or TP-2 if the design determines the infiltration barrier to be unnecessary to stabilize the slopes, minimize erosion, and minimize AMD generation.

The requirement for an infiltration barrier on the non-slope areas of TP-1 and TP-2 as required by the VTSWMR is retained in the EE/CA as an ARAR.

Alternatives 3C and 3D would not comply with the performance standards for a barrier layer on the non-slope portions of TP-1 and TP-2 as specified in the VTSWMR. Alternative 3B would only comply with this ARAR if the bottom 18 inches of soil in the cover were installed with a permeability of 1 x 10^{-5} cm/sec or less. As a result, only the cover systems described in Alternatives 2B, 2C, and 3B would comply with the design standards for the cover systems identified in the VTSWMR.

All alternatives under consideration in this EE/CA involve impacts to historic resources that are eligible for the National Register of Historic Places. Each of the alternatives considered in this report seeks to minimize the impact of the cleanup on the historic resources at the Site. All three tailings piles possess value as historic landscapes. The most immediate and visible historic resources at the Elizabeth Mine are the major landscape elements left from the copperas and copper production activities in the form of tailings or waste rock piles.

The adverse effects of the cleanup on the historic resource include covering or capping TP-1 and TP-2, altering the visual landscape through the addition of the surface water channels and passive treatment systems and the physical removal of portions of TP-3. During design of the selected Alternative, EPA will attempt to maintain a surface topography that retains (to the extent practicable and ARAR compliant) the steep slopes and large plateaus of TP-1 and TP-2, however, the color, texture, and ability to directly observe the tailings will be lost. The top surface TP-1 and TP-2 will be grass or rock-covered and the steep, eroded slopes observed today will become a sloped grass or rock cover. Alternative 2B will result in a more substantial impact to the tailing profile as a result of the excavation of TP-2 and the consolidation of this material onto TP-1.

EPA has indicated an intention to preserve as much of TP-3 as possible and to minimize direct impacts to the copperas works and Tyson-era features. The critical factor in TP-3 preservation is the amount of maintenance that the State of Vermont is willing to accept. At this time the State of Vermont has expressed a preference for Option 1 (complete preservation) provided funding is available to support this position. Upon completion of the Design, EPA will provide a revised estimate of the PRSC costs associated with TP-3 and request that the State of Vermont finalize the decision with respect to TP-3. It is not possible to anticipate the effects of the remediation upon the entire historic property until an alternative is selected and the construction proposal is in the Design stage. At that point, consultation with the SHPO and the other consulting parties will continue to identify impacts and address any additional adverse effects that may be identified. The resolution to the adverse effects will be the outcome of the consultation and will be embodied in the stipulations in the MOA.

4.1.3 Long-Term Effectiveness and Permanence

The five alternatives all provide the same level of long-term effectiveness and permanence with respect to TP-3. The long-term effectiveness and permanence with respect to the treatment of the exposed material remaining at TP-3 is entirely dependent upon the successful design and construction of these innovative treatment systems along with the maintenance (Post-Removal Site Control) of these systems by the State of Vermont. Failure to maintain the passive treatment system would allow the AMD to enter the surface water of Copperas Brook with subsequent impacts to the ecological receptors.

Alternatives 2B and 2C have the highest level of long-term effectiveness and permanence. Alternative 3D may approach the long-term effectiveness and permanence of 2B and 2C if the hardpan is truly uniform, self-healing, and of low permeability. However, re-application of the limestone may be necessary to maintain the effectiveness of the hardpan. Alternative 3B has a somewhat lower level of effectiveness, because it allows greater infiltration of water and oxygen into the tailings. Alternative 3C has the lowest level of effectiveness and permanence, given the thin cover and potential for disturbance and erosion. Alternative 3C is likely to continue to allow significant surface water infiltration and oxygen into the tailings, for the following reasons:

- Considering construction accuracy, the soil cover may be less than six inches in some places and more than six inches in others;
- Cyclic wet/dry conditions and frost/melt events will result in non-uniform infiltration; and
- Six inches of soil is insufficient to maintain a healthy, sustainable vegetative cover.

4.1.4 Reduction in Toxicity, Mobility, or Volume through Treatment

Caps and covers are not considered treatment. However, treatment to reduce the mobility of the contamination will occur in the passive treatment systems. These systems will effectively neutralize the low pH run-off and cause the precipitation and sequestering of the metals within the run-off. The treatment process and effectiveness is largely the same for all five alternatives, therefore, reduction in toxicity, mobility, or volume through treatment is not a distinguishing factor between alternatives, except that the amount of water treated will vary.

4.1.5 Short-term Effectiveness

Short-term effectiveness includes an assessment of the time period until the removal action goals are met. All alternatives should be able to meet these goals shortly after construction is complete. Once the passive treatment systems are fully operational (within 2-3 years of construction), the AMD impacts to Copperas Brook and the WBOR should be eliminated. The cover system for Alternatives 2B, 2C, 3B, and 3C and diversion ditches included in all Alternatives will have the immediate effect of reducing the amount of clean water coming into contact with the tailings and a long-term effect of reducing the flow to the passive treatment system for TP-1.

Short-term effectiveness also considers the magnitude of potential threats to the community, Site workers, and the environment during implementation of a response action. This includes threats that result from implementing the remedy itself as well as existing threats that persist until mitigated by the cleanup action.

All alternatives have a potential for exposure of fresh sulfide material to storm events, since some quantity of unoxidized tailings are likely to be exposed to achieve final grades or consolidate portion of TP-2. The Design will focus on a final slope configuration that minimizes the exposure of un-oxidized tailings. Each alternative involves substantial construction-related activity and truck traffic. Tailings movement from TP-2 to TP-1 and possibly TP-3 to TP-1 is likely to occur over a several month period and require continuous truck traffic during working hours along a small portion of Mine Road unless an alternate route is identified. This activity should not result in a direct impact to the village of South Strafford; however local residents in the Mine Road area would be directly impacted. However, at this time, EPA must assume that all of the materials required to construct the cover systems will be brought to the Site from an off-site location. EPA will attempt to locate and reach agreement with adjacent landowner regarding the use of locally available soil material to reduce truck traffic in the public roads. The estimated trucks required for delivering construction materials for each alternative are shown in the table below:

Alternative	***Estimated Truck Count For Cap/Cover[1,2] (Round Trips)***
Alternative 2B	7,765
Alternative 2C	7,765
Alternative 3B	17,992
Alternative 3C	3,851
Alternative 3D	9,287

1. A two-season construction period has been estimated,
2. Estimations based on 12 cubic yard truck volume.

The surrounding towns, including Norwich, Sharon, Strafford, and Thetford, may be affected by increased truck traffic, noise, dust, and road surface degradation. Road weight limits, soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect truck traffic volume. If a soil borrow pit is identified near the Site, traffic impacts may be reduced to a small area especially if roads can be constructed through the woods from the Site to the soil borrow pit.

Potential risks to Site workers arise from performing construction activities and from exposure to contaminants in tailings, soil, groundwater, and air. Potential risks will be controlled by development and adherence to a site-specific Health and Safety Plan.

4.2 Implementability

4.2.1 Technical Feasibility

It is technically feasible to implement each of the five alternatives. Design and construction of the cap/soil cover system and the surface water diversion channels use proven and easily implemented technologies. For all alternatives, the tailings slopes will be stabilized using some combination of slope re-grading, rip rap, or buttressing. All of these techniques have been used in construction and slope rehabilitation of many tailing piles and landfills.

It is technically feasible to build the passive/natural treatment system for all alternatives. There are some concerns with respect to the ability of the passive treatment technology to achieve water quality criteria for all constituents for TP-3 as well as the cold weather performance of these systems.

Accepting the objective that the cleanup be a community-based solution, with strong support from the State of Vermont, this EE/CA has been developed based upon the State of Vermont's and local community's preference for leaving as much of TP-3 in place as possible. This objective is based upon the historic value of TP-3. This goal is achievable, but requires a level of engineering and scientific ingenuity that goes beyond more conventional remediation approaches. Leaving TP-3 in place also introduces additional operation and maintenance activities, and their corresponding costs, in-perpetuity. EPA is prepared to undertake, with an expectation of success, the challenge of designing a remediation alternative that considers leaving TP-3 in place.

Leaving TP-3 in place requires a waiver of the Vermont Solid Waste regulations relative to slope and cover requirements. The current regulations require that TP-3 be flattened to a slope much less steep than the current slope configuration and also requires that all waste material be covered with a low permeability cover system.

The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for copper. EPA expects that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. EPA will undertake bench and pilot-scale treatability studies to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal.

Since the passive treatment systems are the same for each Alternative, technical feasibility of these systems is not a strong distinguishing factor among alternatives.

4.2.2 Administrative Feasibility

Implementation of any of the alternatives in this EE/CA will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate state and local agencies will be required to implement any of the alternatives. Construction involves direct and indirect impacts to both the town and the local residents through truck traffic, noise, and dust. EPA will coordinate with the Vermont Agency of Transportation, town Select Boards and the local community regarding traffic impacts and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Norwich, Strafford, Sharon, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the town Select Boards.

Administrative feasibility is not, therefore, a strong distinguishing factor among alternatives.

4.2.3 Availability of Services and Materials

The differences between alternatives are largely related to cap and cover construction materials and the necessary service expertise for installation/construction. Common borrow material and topsoil are needed for each of the alternatives. Crushed limestone is needed for passive treatment systems in each alternative and the hardpan cover (3D). Availability of services and materials should not be a constraint for any of the alternatives under consideration. On the basis of this criterion, none of the five alternatives are more or less desirable.

4.2.4 State and Community Acceptance

State and community acceptance will be addressed through the public comment process.

EPA has worked closely with the State of Vermont and local communities to develop the short list of alternative response actions represented in this EE/CA. Throughout this process, the community has clearly articulated their concerns and desires. The state has been involved in all aspects of the planning and community outreach process.

Community concerns include the following:

- Effectiveness of the cleanup;
- Preservation (to the extent practicable) of Site elements with historic/cultural value;
- Limiting truck traffic and construction impacts to the community;
- Scale and cost of the cleanup; and
- Innovation, re-use, and education.

4.2.5 Effectiveness of the Cleanup

The alternatives can be distinguished on the basis of Effectiveness of the Cleanup. Alternatives 2B and 2C will be most effective at reducing AMD over the long-term, while Alternative 3C will be the least effective. Uncertainties remain concerning the effectiveness of an induced hardpan layer in Alternative 3D. The long-term maintenance of the passive treatment systems is the most critical element of effectiveness for the treatment of the TP-3 run-off. The long-term effectiveness and permanence with respect to the treatment of the exposed material remaining at TP-3 is entirely dependent upon the successful design and construction of these innovative treatment systems along with the maintenance of these systems by the State of Vermont.

Preservation of Historic Site Elements. The response alternatives described in this EE/CA will all have an impact on the physical integrity of the historic landscape and resources at the Elizabeth Mine. The impacts from Alternatives 2C, 3B, 3C, and 3D will be largely indistinguishable. Alternative 2B will have a more profound impact on the physical appearance as a result of the physical removal of TP-2.

The SHPO and the community have a strong preference for alternatives that will minimize the impact on features of historic significance, including the mining landscape itself. As a result, the EE/CA has developed cleanup alternatives that minimize or eliminate construction activities near most features of historic significance, including the WW II-era buildings and the remains of buildings from early copperas and copper production.

During scoping meetings, discussions identified the attributes of the site that are most valued by the community. They include the copperas works, the Tyson-era associated features, standing structures, Furnace Flat, the North and South open cuts, and the overall industrial landscape reflected by the tailings and waste rock piles.

The alternatives presented in the EE/CA were developed jointly by EPA, the State, and the community in an effort to evaluate alternatives that could achieve the cleanup objectives and minimize the impact of NTCRA actions on the mining landscape. None of the alternatives will have a substantial direct impact on standing structures, Furnace Flat, or the open cuts. The adverse effect for the five alternatives will be defined by the impact on the mining landscape that will alter the integrity of the setting, location of features, associations and relationships of the different mining periods and the feelings associated with the historic landscape.

EPA intends to preserve as much of TP-3 as possible and avoid direct impacts to the copperas works and Tyson-era features. The critical factor in TP-3 preservation is the amount of maintenance that the State of Vermont is willing to accept. It is not possible to anticipate the nature of the effects of the remediation upon the entire historic property until an alternative is selected and the construction proposal is in the Design stage. At that point, consultation with the SHPO and the other consulting parties will continue to identify impacts and address any additional adverse effects that may be identified. The resolution of the adverse effects will be the outcome of the consultation and will be embodied in the stipulations in the MOA.

Limiting Truck Traffic:
While each of the alternatives will require a large number of trucks to transport cover/cap material and other construction materials to the Site, the alternatives presented in this EE/CA vary considerably in terms of the amount of truck traffic that is likely to occur. Alternative 3B will require the largest number of trucks (approximately17,992), while Alternative 3C will require the fewest (approximately 3,851 trucks). The other alternatives have a similar level of truck volume required to bring the materials to the Site. Truck traffic over town roads may be significantly reduced if local sources of common borrow material can be located and acquired. Alternative nearby sources will be evaluated in the Design phase.

Scale and Cost of the Cleanups:
From the beginning of EPA's involvement, the local community has expressed concerns about the scale and cost of the cleanup. Variations in scale and cost between alternatives are largely a function of the cap/cover construction specifications. Geomembrane caps require more engineering control and construction care, whereas soil covers are generally less complex, but also potentially less effective. The current range of alternatives represent a set of options that are comparable in scale and costs and represent reasonable approaches to the environmental problems at the Site. The VTSWMR, which apply to this project, require a barrier layer over the waste. As a result only Alternatives 2B, 2C, and 3B meet the basic regulatory requirements for evaluation in terms of scale and cost.

More detailed information regarding the estimated cost of the various alternatives is included in Section 5.3. State and community acceptance and concerns regarding the scale and cost of the cleanup will be further considered following receipt of comments during the public comment period.

Innovation, Re-use, and Education:
EPA believes that most of the cleanup alternatives (2B, 2C, 3B, and 3D) would include the use of innovative technologies regarding infiltration reduction. The passive treatment systems included in all of the alternatives are an emerging innovative technology. EPA agrees that re-use and education are valuable components of any cleanup. EPA has provided the community with a re-development grant to facilitate a community dialogue regarding Site re-use. EPA has been meeting with the landowners to address liability issues that could be a barrier to

re-use. EPA provided a Technical Assistance Grant to the community to provide additional technical support to the community. Finally, EPA will continue to support outreach and education activities with respect to the Site.

On November 19, 2001 the EMCAG sent EPA a letter in response to the draft EE/CA. The key sections of that letter are presented below:

> *"As you know, the EMCAG is committed to developing a cleanup that resolves environmental problems in a way that is sensitive to community issues –especially traffic—and protects historic resources. We applaud you for the work you have done in developing alternatives that address the issues we have raised.*
>
> *We are attaching hereto copies of comments from our technical consultants Richard Downer and Woody Reed, and will summarize our other concerns below.*
>
> **Passive Treatment Systems**
>
> *As noted in his reports, Woody Reed has assured us that passive treatment systems can be designed to achieve the specified water quality goals. Considerations for the final selection of process components should include the response to our cold winter environment, costs, and maintenance requirements. We are pleased that a natural treatment system will be part of the final cleanup design.*
>
> **Cover System Thickness**
>
> *We want to minimize cleanup-related traffic impacts to our communities. Toward that end, we ask that you reduce the thickness of the cover system to the extent practicable without compromising the long-term effectiveness of the cleanup. We would also like the cover system to be designed to accommodate future use of the Site. We do not yet have a collective vision regarding the future use(s) of the site, but have a consultant that will be working with the towns under a Redevelopment Initiative Grant to develop a vision for the site's future.*
>
> *We strongly support your proposal to look for onsite sources of common borrow. We also encourage you to develop a cover system that does not require large quantities of topsoil that would need to be stripped from productive farm or forest land.*
>
> **Goals of the Cleanup**
>
> *Nine of our ten member groups support the goals of the cleanup, as described in the draft EE/CA. The group Citizens for a Sensible Solution (CASS) believes that the goal of designing the wetlands systems so that the receiving waters meet VT WQS is overly restrictive. CASS also believes that the cleanup should not be done under the NTCRA authority, but rather should be conducted under the Remedial process.*
>
> **TP3**
>
> *Most of our member groups support the preservation of the historically significant features of TP3 to the extent practicable, provided that the cleanup goals can be met and that the State of Vermont can afford and commit to paying the associated operation and maintenance costs. We would like more information about environmental "hot spots" within TP3.*
>
> *We encourage you to explore "soft" engineering approaches to erosion control to stabilize the TP3 landscape and reduce O & M costs. We suggest that part of TP3 might be used to test innovative cleanup technologies that are designed to be compatible with historic landscapes.*
>
> **Operation and Maintenance Costs**
>
> *Several CAG members, appreciate the ANR's statements that they intend to come up with the funding to cover future O&M costs, but believe that it is impossible to guarantee that this*

funding will be there forever. Therefore, they support a cleanup that minimizes future O&M.

Alternative Selection

Seven of our member organizations voiced a preference for Alternative 2B; two prefer Alternative 2, but do not have a preference between 2B and 2C; one group does not support any of the alternatives described in the draft EE/CA, and proposes limiting the NTCRA to the construction of diversion ditches and passive wetland treatment systems.

Future Use and Aesthetics

As you know, EPA has granted us money through the Redevelopment Initiative to consider future use options at the site. This initiative is in its infancy, and we ask that you leave enough flexibility in the design phase so that fairly passive land uses (such as recreation and historical and environmental interpretation) can be accommodated.

We are mindful that the physical aspects of the cleanup will be with us for generations to come. Consequently, we ask that addressing aesthetic considerations be a part of the design phase. In particular, we hope that vegetated buffers can be preserved and maintained between town roads and construction wherever possible, that staging areas be selected based in part upon their impact on viewsheds, and that the design of the drainage ditches, holding ponds and wetlands include some visual interest."

EPA believes Alternative 2C provides a balanced approach to achieving the EMCAG concerns stated above.

4.3 Costs of Response Alternatives

The estimated cost to complete each of the response alternatives is provided in Table ES-1. The cost difference between Alternatives 2B, 2C, 3B, and 3D is within the margin of error (for cost estimation); therefore, these alternatives are essentially equal in cost. Alternative 3C has the lowest cost of the alternatives, however, this alternative has significant concerns with respect to long-term effectiveness and is not compliant with the VTSWMR.

4.4 Differentiators Among Alternatives

In summary, the alternatives that have been described and evaluated in this EE/CA are very similar when evaluated against most of the evaluation criteria. There remain significant concerns as to whether Alternative 3C has sufficient thickness of soil to provide long-term protection against erosion and whether the thin cover would support vegetation. The major difference between the alternatives is the approach to reducing the generation of AMD from TP-1 and TP-2. Alternatives 2B and 2C offer the greatest reduction in infiltration of water and oxygen and subsequent AMD formation followed by 3D, 3B, and 3C. One critical difference between alternatives is that only Alternatives 2B, 2C, and 3B comply with the VTSWMR.

EPA has used the information and analysis contained in this EE/CA to develop a Proposed Plan (fact sheet) that will present the alternative that EPA believes is the best approach to address the contamination at the Site. This EE/CA and the Proposed Plan will be subject to a public comment period. EPA will consider the public comments and issue a decision document (Action Memorandum) along with a response to comments to formally select a cleanup alternative.

Northwest edge Tailings Pile 1 with some remaining mine buildings

View looking South from Tailings Pile 1 to the face of Tailings Pile 2

Seeps from the toe at Tailing Pile 1

View of Tailings Pile 1 and Copperas Brook Ponding Area looking Northeast

Looking East from Copperas hill (ca. 1908)

"Upper" waste rock and heap leach piles (TP-3), below north mine cut

East Side of Copperas Hill, with Elizabeth Mining Company (Tyson) mill buildings (ca. 1900)

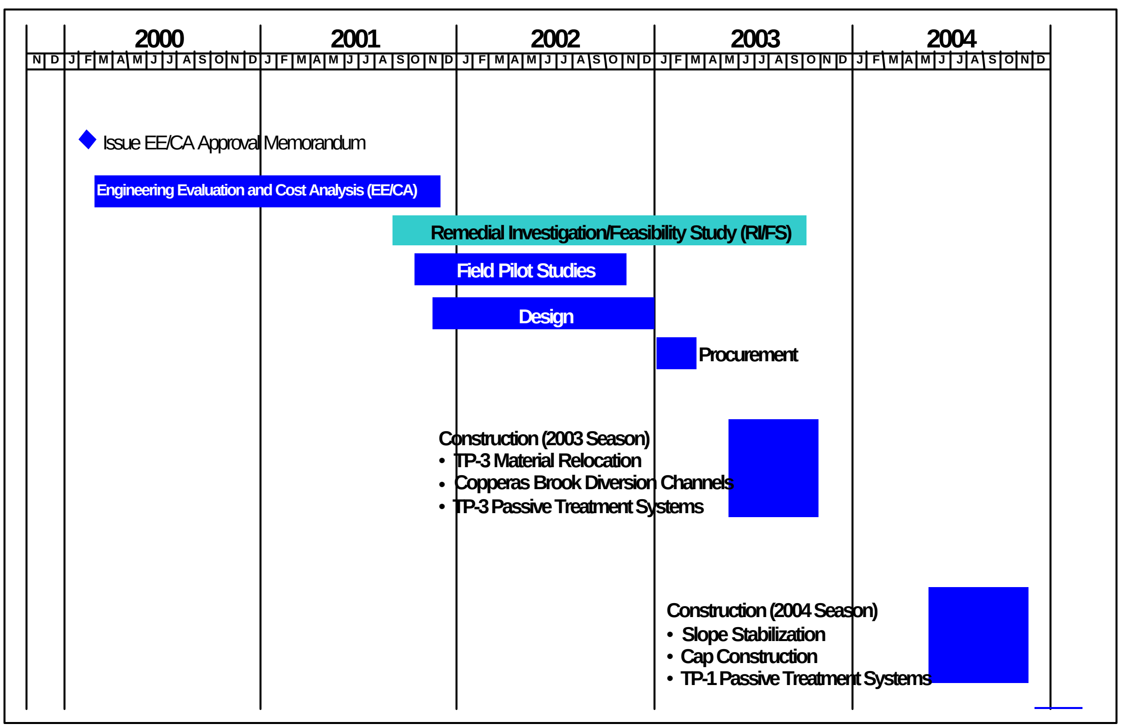

Figure ES-1: Schedule for Removal Action

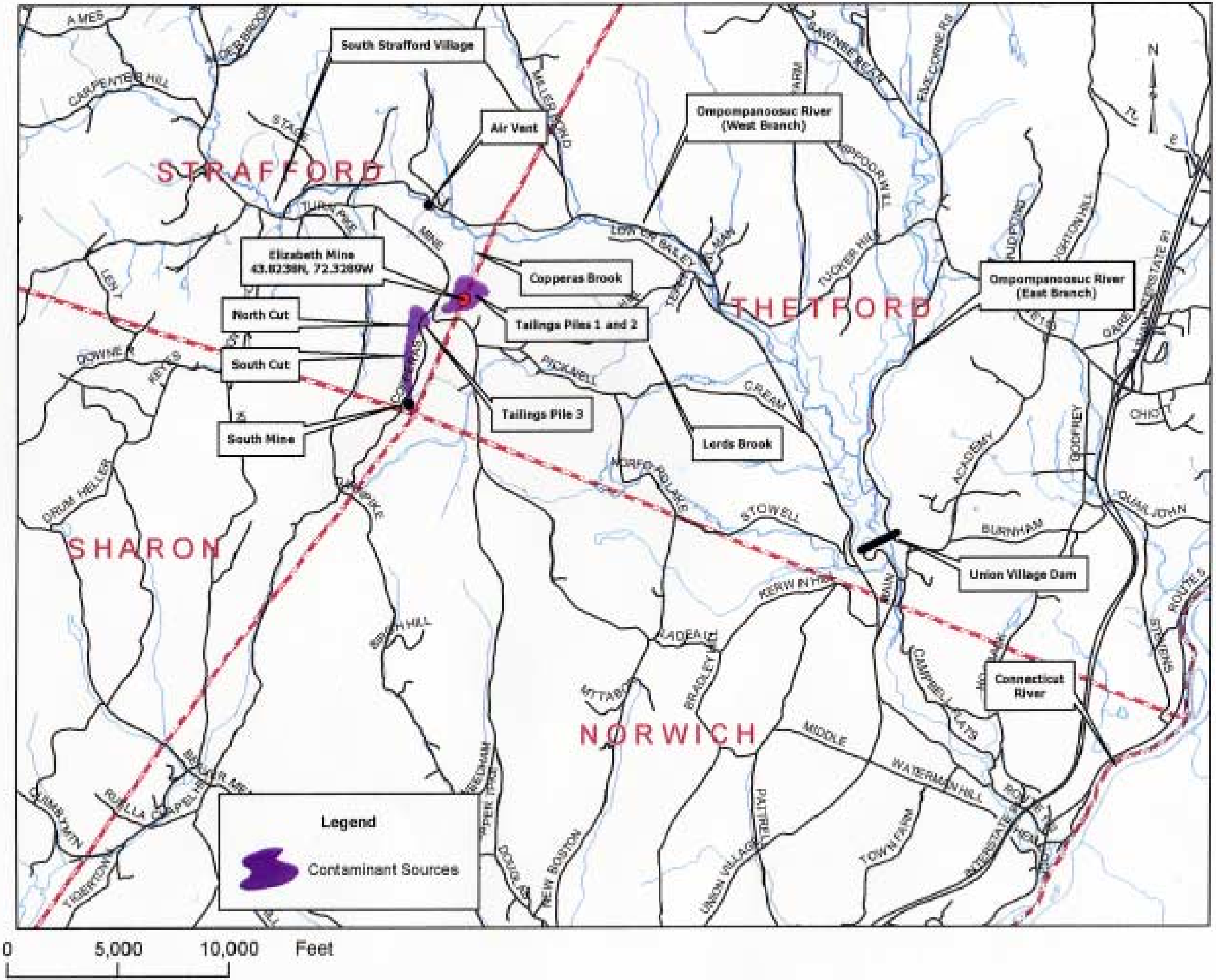

Figure ES-2 - Site Location Map

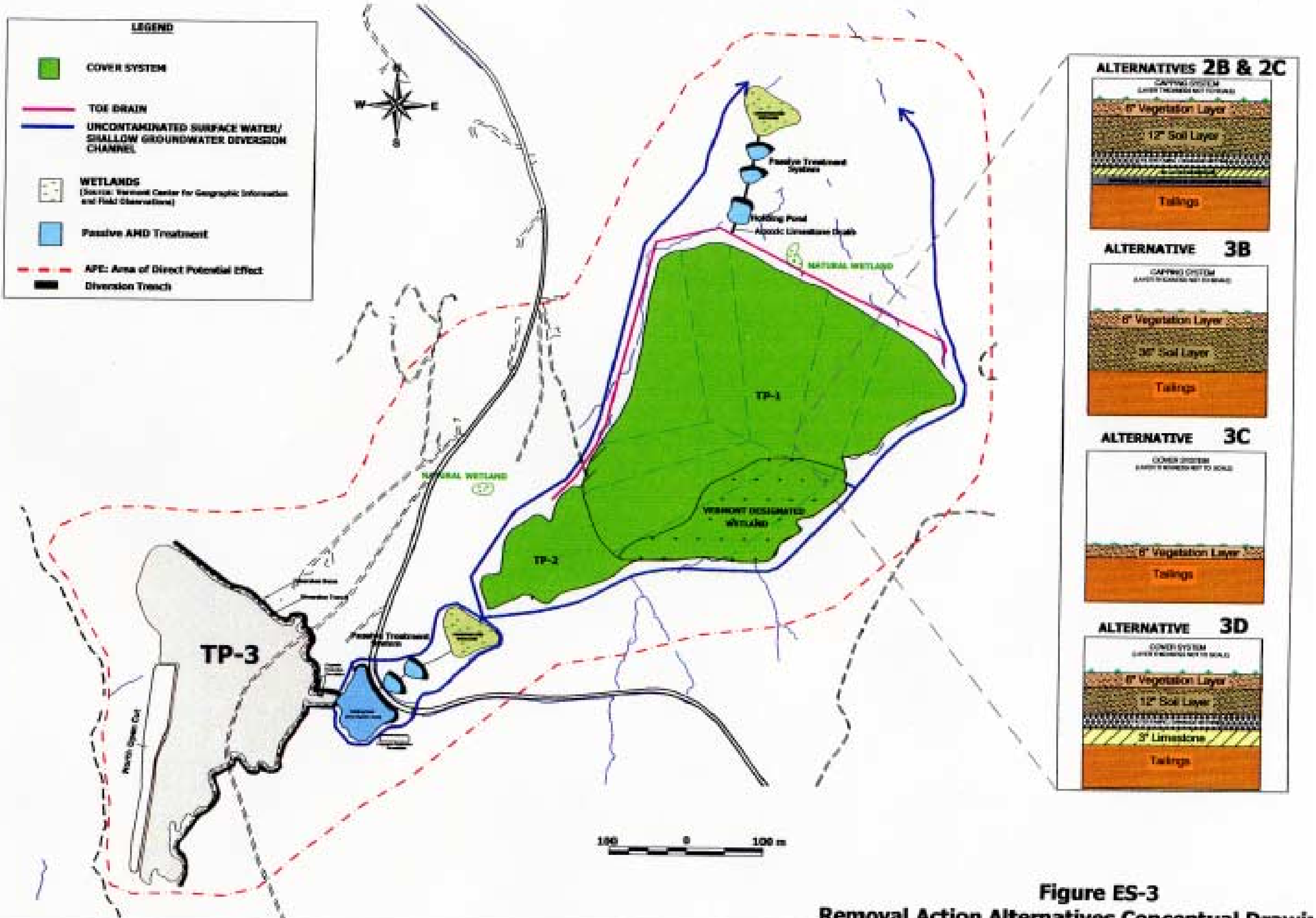

Figure ES-3
Removal Action Alternatives Conceptual Drawi

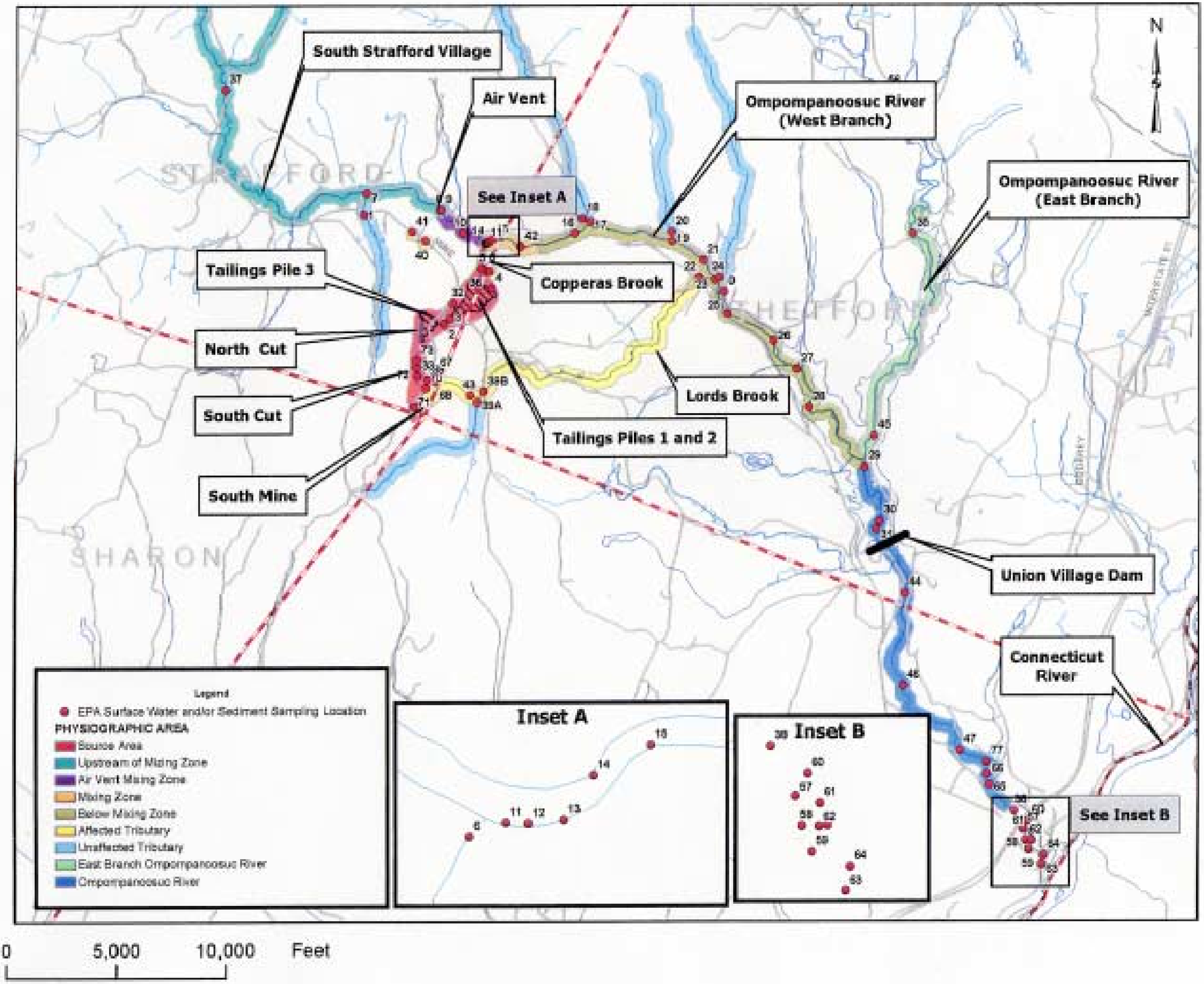

Figure ES-4 - Potential Areas of Contamination

Table ES-1: Elizabeth Mine Cleanup Cost Table

Elizabeth Mine Cleanup Cost Table

Option 1 (100% Preservation of TP-3); Option 2 (50% Preservation of TP-3); Option 3 (20% Preservation of TP-3)

Cleanup Alternatives		2B Infiltration Barrier Cap (Geomembrane) on TP-1 and Remove TP-2	2C* Infiltration Barrier Cap (Geomembrane) on TP-1 and TP-2	3B Soil Evapo-Transpiration Cover on TP-1 and TP-2	3C Six Inch Soil Cover on TP-1 and TP-2	3D Chemical Cap (Hardpan) with Soil Cover on TP-1 and TP-2
Capital Costs	Option 1	$13,629,811	$12,902,894	$12,313,256	$9,414,895	$12,040,253
	Option 2	$15,153,866	$14,426,949	$13,837,778	$10,938,950	$13,564,308
	Option 3	$16,200,818	$15,473,901	$14,884,263	$11,985,902	$14,611,260
PRSC Activity	TP-1 Maintenance	$82,220	$89,974	$109,622	$131,918	$90,276
	TP-3 Maintenance (Option 1 – Complete Preservation of TP-3)	$254,359 - $400,523	$254,359 - $400,523	$254,359 - $400,523	$254,359 - $400,523	$254,359 - $400,523
	TP-3 Maintenance (Option 2/3 – Preservation of 20%-50% of TP-3)	$153,259 - $200,940	$153,259 - $200,940	$153,259 - $200,940	$153,259 - $200,940	$153,259 - $200,940
Total Annual State Costs	Based on TP-1 and TP-3 Option 1	$336,579 - $482,743	$344,333 - $490,498	$364,021 - $510,186	$386,277 - $532,441	$344,635 - $490,799
	Based on TP-1 and TP-3 Option 2/3	$235,479 - $283,161	$243,234 - $290,915	$262,922 - $310,603	$285,177 - $332,859	$243,535 - $291,216

Notes:

(1) All alternatives include: a surface water/groundwater diversion to divert clean water around TP-1 and TP-2; filling the decant tower, and passive treatment of the seeps of TP-1 and the run-off from TP-3.

(2) All alternatives include measures to stabilize the slopes of TP-1 and TP-2 as determined during geotechnical design studies and as required by VT Solid Waste Management Rules (unless these are waived by ANR).

(3) The range in TP-3 costs for each option are based upon the assumptions for the disposal of the sludge generated by the passive treatment systems. The low end cost assumes off-site disposal as a non-hazardous solid and the high end cost assumes off-site disposal as a hazardous waste liquid.

(4) All costs are presented as an annual amount the State of VT would need to appropriate into a fund to handle annual and periodic replacement costs. The present value is not presented.

* Alternative 2C is EPA's preferred cleanup option.

1.0 Introduction

1.1 Purpose and Scope

This Engineering Evaluation/Cost Analysis (EE/CA) was prepared by Arthur D. Little (ADL) for the U.S. Environmental Protection Agency (EPA) pursuant to an interagency agreement with the U.S Army Corps of Engineers (USACE), New England District. The EE/CA provides an engineering evaluation to support the selection of a Non-Time-Critical Removal Action (NTCRA) for the Elizabeth Mine Superfund Site (the "Site") in Strafford and Thetford, Vermont. EPA is the lead federal agency at the Site. Investigations at the Site have identified conditions that correspond to factors in Section 300.415(b)(2) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 C.F.R. 300.415). These conditions indicate that a NTCRA may be necessary to abate, prevent, minimize, stabilize, mitigate, or eliminate threats to human health and the environment.

The EPA has categorized three types of removal actions: emergency, time critical, and non-time-critical. These designations are based on the urgency with which cleanup must be initiated to respond to a threat to human health and the environment posed by a release or potential release of hazardous substances. Emergency and time-critical removal actions are initiated to respond to a release or potential release where less than six months are available for planning the response. A NTCRA may be implemented in cases where more than six months are available for planning a response to a release or potential release. Section 300.415(b)(4)(I) of the NCP requires the development of an EE/CA along with a public comment period, prior to the signing of the Action Memorandum, to initiate the NTCRA. In February 2000, EPA signed an Approval Memorandum (see Appendix A) authorizing the preparation of this EE/CA for the Elizabeth Mine Site. The Approval Memorandum is the first step in the NTCRA process.

The EE/CA identifies removal action objectives for protection of human health and the environment, identifies removal action alternatives, and assesses the effectiveness, implementability, and cost of the alternatives that satisfy the removal action objectives. The EE/CA considers the nature of the contamination, any potential risks to human health and the environment, and how the alternatives fit into the overall strategy for site remediation.

The scope of the Elizabeth Mine NTCRA addresses the waste material deposited at the surface of the Site from historic heap leaching, mining and milling operations, including three tailings and mine waste piles (Tailings Pile 1 [TP-1], Tailings Pile 2 [TP-2], and Tailings Pile 3 [TP-3]) and the tailings that have eroded off the slope of TP-1. By addressing this source material, the creation and migration of acid mine drainage

(AMD) from most of the Site will be eliminated or substantially controlled. The approach and cleanup alternatives for the NTCRA are consistent with the long-term remediation goals of the Site to be addressed during the Remedial Investigation/Feasibility Study (RI/FS) phase.

1.2 Report Organization

This report is organized into six sections:

- Section 1.0: Introduction
- Section 2.0: Identification of Removal Action Scope and Objectives
- Section 3.0: Development of Removal Action Alternatives
- Section 4.0: Analysis of Removal Action Alternatives
- Section 5.0: Comparative Analysis of Removal Action Alternatives
- Section 6.0: References

1.3 Site Description

The Elizabeth Mine is located on the Strafford/Thetford town line at Latitude 43.8239 and Longitude 72.3289 in east-central Vermont, approximately 1.9 miles southeast of the village of South Strafford, on the eastern flank of Copperas Hill. (see Figure 1-1). The Site contains six distinct potential contaminant source areas:

- The three tailing piles and mine waste areas (TP-1 [30 acres], TP-2 [5 acres], and TP-3 [12 acres]) located in the Copperas Brook watershed represent sources areas one, two and three.
- The continuous discharge of ground water from the underground workings, referred to as the “air vent” is the fourth potential source area.
- The South Open Cut is the fifth potential source area.
- The South Mine is the sixth potential source area.

The general boundaries of the Superfund Site include those areas of the Elizabeth Mine that contain hazardous substances, pollutants, or contaminants released from the Site, including any source areas, as well as areas required for the implementation of any cleanup actions.

1.3.1 Historical Summary

The Elizabeth Mine massive sulfide ore body was discovered along a ridge located southeast of South Strafford village in 1793. The mine was initially worked for the sulfide mineral pyrrhotite to manufacture copperas, an iron sulfate, used for a variety of purposes, including dye and disinfectant manufacturing. In 1830, Strafford Copper Works was formed to exploit the Site for copper. During the early mining operations, copper was smelted on-site. Underground mining began in the early to mid-1800s. The mine was worked intermittently from 1830 until 1930 when it closed. In 1942, the mine reopened in response to World War II and was operated by Vermont Copper Company. Most of the underground copper mining occurred between 1942 and the mine's final closure in 1958.

Following the end of mining operations in 1958, the mine property was divided into two parcels and sold. A 400-acre tract, including the 1940s and 1950s-era buildings and TP-1 and TP-2, was purchased by Leonard Cook in the early 1960s and used for storage of construction business equipment. In the 1970s, Mr. Cook auctioned all but 67 acres of the property. The remaining parcels of land that were part of the mine have all been sold to individuals who use the land for recreational, timber harvesting, and residential purposes. Two areas of the Site were used for gravel and soil extraction. The Site is no longer being used for commercial purposes. The town-maintained road that runs through TP-3 is used for logging access, walking, biking, and other forms of recreation.

The tailings in TP-1 and TP-2 were generated through the milling of sulfide ores between 1942 and 1958. A sulfide flotation mill was constructed during this period, where the ore was refined and the resulting concentrate was shipped to off-site smelters. The flotation mill allowed for efficient recovery of minerals from ore with small percentages of copper. In the flotation circuit, fine-grained particles of the copper-bearing mineral chalcopyrite were extracted. The remaining material was pumped to settling ponds, resulting in the formation of the tailings piles. Today, an orange iron-oxide rich "rind" covers the surface of TP-1 and TP-2 to a depth of one to two feet below the tailings surface. Below this oxidized cap, a uniform layer of black sulfide-rich anoxic tailings extends to the base of each pile.

The waste rock and "heap leach" piles situated to the northeast of the North Cut are referred to as TP-3. Colorful piles of variably pyrolyzed sulfide ore are present over an area of approximately 12 acres. These residues are a result of the production of copperas (iron sulfate) throughout the 1800s. Waste rock from the late 1800s copper mining activities are also situated within TP-3cover portions of the copperas wastes. Adjacent to the open North Cut, especially toward the southern end of the cut, additional waste rock piles from copper mining are mixed with the sulfides used for copperas production. This material appears to have resulted from slope-stabilization cutbacks in the North Cut during the mid to late 1800s.

In-depth and further discussions of the mine history can be found in the following reports prepared by ADL and their subcontractors:

- *Statement of Site Limits, National Register Eligibility, and Potential Resources in the Proposed APE: Elizabeth Mine, South Strafford, Vermont*. Hartgen Archeological Associates, October 2000
- *Historical Context and Preliminary Resource Evaluation of the Elizabeth Mine.* Public Archeology Laboratory and Arthur D. Little, Inc. May 2001
- *Elizabeth Mine Site Summary Report.* Arthur D. Little, Inc., October 2000

- *Elizabeth Mine Site Conditions Report*. Arthur D. Little, Inc., February 2001
- *Elizabeth Mine Environmental Response Alternatives Analysis Report*. Arthur D. Little, Inc., April 2001

1.3.2 Statement of Significance

The Elizabeth Mine is a significant historic resource on local, state, and national scales. The Site embodies the distinctive landscape, engineering, and architectural resources that are characteristic of an early nineteenth- to mid-twentieth-century American metal mining and processing site. The Site constitutes one of the largest and most intact historic mining sites in New England and includes the only intact cluster of hard-rock mining buildings in the region.

Historically, the Elizabeth Mine was the site of a major nineteenth century U.S. copperas manufacturing plant and is associated with successful patents for copperas production. It is also associated with a number of significant commercial, scientific, and political figures, including Isaac Tyson, Jr., a Baltimore, Maryland-based chemical and mining figure who was recently inducted into the American Institute of Mining, Metallurgical and Petroleum Engineers' (AIME) Mining Hall of Fame.

EPA has determined the Elizabeth Mine Site to be eligible for listing on the National Register of Historic Places. Historic property boundaries, as determined by the eligibility assessment for the National Register of Historic Places and as accepted by the Vermont State Historic Preservation Officer (SHPO), are inclusive of copperas- and copper-mining landscapes formed during the late-eighteenth to mid-twentieth centuries. Historic and archaeological resources, which include ore extraction and processing sites, support infrastructure, and waste deposits, are distributed over approximately 500 acres, extending from Copperas Hill northeast to the West Branch of the Ompompanoosuc River (WBOR) and southward to Lord Brook. Portions of the historic property will be directly and indirectly impacted by cleanup activities. For historic resource management purposes, the areas of direct impact include mine waste deposits (TP-1, TP-2, and TP-3) and areas favored under some options for the installation of treatment systems. Indirect effects include potential impacts during the NTCRA to all other areas of the historic property. Indirect affects for the historic property, as well as potential direct impacts to an area identified as the "South Mine", are not included in the scope of this EE/CA, and will be addressed during the design of the NTCRA.

EPA will comply with the National Historic Preservation Act (NHPA) as part of any undertaking to address environmental pollution. In accordance with the NHPA, EPA has fully evaluated measures to avoid and/or minimize impacts to historic properties and features of the Site. These impacts are unavoidable and necessary to perform the cleanup, therefore EPA will enter into a Memorandum of Agreement (MOA) with the appropriate parties to outline actions to avoid, minimize, or mitigate adverse effects to the historic properties.

1.3.3 Surficial and Bedrock Geology

The Elizabeth Mine Site is located approximately 10 miles west of the Connecticut River. The surficial material in the region can largely be attributed to its glacial history, giving rise to the three principal surface overburden units present in the area. The units consist of a dense glacial basal till (resting on bedrock), locally overlain with a sand and gravel outwash deposit. Both deposits are overlain by thin Quaternary alluvium (sand and gravel) in drainage channels. Each unit varies in thickness and distribution. The North Open Cut and three tailing piles (TP-1, TP-2, and TP-3) are situated on the east flank of Copperas Hill, between the elevations of 850 (base of TP-1) and 1,400 feet above sea level (North Mine Cut).

Directly underlying TP-1 and TP-2 is a thin layer of gravel/sand/debris representing the pre-tailings ground surface. This thin, water-bearing horizon appears to be no more than two to three feet in thickness. Directly under this horizon is a glacial basal till sequence, measuring as much as 75 feet in thickness. The basal till rests directly on crystalline bedrock. Core samples of the till indicate that it is highly compact, dry, and comprised of rock fragments in a clay/silt matrix. TP-3 waste rock and heap leach piles are directly underlain by crystalline bedrock.

The headwaters of the WBOR are underlain in part by the Devonian Waits River Formation, consisting of metamorphosed calcareous shale, and minor quartzite, limestone, and dolostone, as well as the Devonian Standing Pond Volcanics, comprised of metamorphosed basalts. The West Branch flows through the Devonian Gile Mountain Formation, the host rock of the sulfide deposit, which consists of metamorphosed black shales and graywackes, with lesser metamorphosed sandstones, calcareous shales, and diabase (Slack, 1993). The high hardness and alkalinity observed in the surface waters of the WBOR can be attributed to the calcareous nature of the rock units upstream of the mine Site.

The massive sulfide deposit at the Elizabeth Mine consists of a series of narrow, tabular ore shoots, dipping steeply to the east, plunging to the north, and extending intermittently over a strike length of more than a mile in a north-south direction. The deposit is characterized as a “Besshi-Type” massive sulfide, comprised largely of pyrrhotite with minor concentrations of chalcopyrite (copper-iron sulfide, 2-5%), and pyrite (iron sulfide). Similar deposits include Ducktown, Tennessee, Fontana, and Hazel Creek mines, North Carolina, and the Windy Craggy deposits in British Columbia, Canada. The sulfide minerals were originally deposited in a deep-sea fumarolic setting, within a mixed sediment and volcanic depositional environment. Mid- to Early Paleozoic metamorphism of the sedimentary sequence resulted in a complex structural setting, where the original units have been tightly folded and overturned, and the sulfide minerals have been remobilized to the hinge zones of the dominant north-south (axis) folds. Within Vermont, massive sulfide deposits similar to those found at Elizabeth Mine also occur at Pike Hill and at the Ely Mine. These three deposits, as well as several smaller deposits/prospects, are referred to as the Vermont Copper Belt.

1.3.4 Climate

The Elizabeth Mine is situated in east-central Vermont, east of the Green Mountains and west of the White Mountains of New Hampshire. The climate in this region is temperate, with a large range of diurnal and annual temperatures and significant differences between the same seasons from year to year. Annual precipitation (snow and rain) averages 35 inches, as measured at the nearby Union Village Dam. Average snow accumulation typically ranges from 3 to 5 feet.

1.4 Previous Removal Actions

1.4.1 Previous EPA Cleanup Actions

There have been no previous EPA cleanup actions at the Site.

1.4.2 Response Actions by the State of Vermont or Federal Agencies

In 1988, the U.S. Army Corp of Engineers (USACE) discovered four large transformers in the TP-2 area that appeared to be leaking. USACE notified the Vermont Department of Environmental Conservation (VTDEC) of the transformers for follow-up investigation. The mine owner claimed that equipment at the mine belonged to the former mine owners and that the transformers had been on the property since 1946. The owner pointed out the presence of 12 smaller transformers in one of the mine buildings. USACE discovered 16 additional smaller transformers in the compressor building. In November 1991, VTDEC sampled the transformers for polychlorinated biphenyls (PCBs). The analytical results indicated that one transformer contained over one gallon of PCB oils. In February 1992, the owner was requested under Title 10 V.S.A. Section 1283 to remove the oil for proper disposal. In March 1992, the owner notified the VTDEC that he had complied with the removal order.

In July 1989, it was discovered that the mine was being used as an illegal dumpsite for out-of-state construction/demolition debris and possibly for industrial/domestic sewage sludge. The dumpsite was located in the central portion of TP-1. Excavation pits were dug in the dump area to determine if hazardous wastes were present. During excavation, soils were analyzed with a photoionization detector and samples of a sludge-like material were collected by VTDEC for analysis. The only metals detected above the method detection limits were lead (250 ppb) and zinc (8,400 ppb). No semivolatile organic compounds (SVOCs) were identified by Method 8270 analysis. A total of nine volatile organic compounds (VOCs) were identified by Method 8240 analysis. Two compounds present in the sample were acetone (17 ppb) and an unknown phthalate ester (40 ppb). The sludge and debris were left in-place and the excavated soil back-filled. No removal actions were undertaken. The owner subsequently covered portions of TP-1 (up to 60%) with a thin soil cover. Indigenous species of grass and acid-tolerant trees and shrubs have established themselves on the soil cover.

1.5 Previous Investigation

The Site Summary Report (ADL, 2000) and Site Conditions Report (ADL, 2001a) both contain a summary of the surface water investigations conducted by EPA and the associated data collected prior to EPA involvement in 2000. An assessment of the quality and usability of the data collected prior to EPA involvement has not been performed; these data therefore must be considered qualitative and of unknown reliability. Data collected by Arthur D. Little, Inc. for EPA are presented in the following reports: *Site Conditions Report* (ADL, 2001a), *Summary of Preliminary Ecological and Human Health Risk Evaluations* (ADL, 2001b), and *Alternatives Analysis Report* (ADL, 2001c).

EPA has collected surface water samples at a total of 64 locations throughout the Elizabeth Mine area. Surface water sampling is summarized in the table below.

Sampling Event	Description of Event	Number of Occurrences
Weekly	April – May 2000, 2001: Weekly stream sampling at source area, reference and downstream locations to evaluate spring runoff metals and pH loading. Locations sampled in 2000 include:1,2,5,6,8,12,33; 2001 locations include: 2,4,6,7,8,25	9
Monthly	April, June, Oct. – Dec. 2000, Jan. 2001: Monthly sampling – subset of locations	6
Synoptic – all stations	May, July, September 2000; May, September 2001 - All locations	5
Episodic (Storm Event)	June and July 2000 – Locations 2,6,7,8,13,16	2

The number of locations and analyses varied between sampling events as the program was refined and as data gaps were identified, as described below:

- April 2000: a subset of 17 locations was sampled for total metals, alkalinity, total suspended solids (TSS), total dissolved solids (TDS), and hardness.
- May 2000: 45 locations were sampled for total metals, dissolved metals, alkalinity, TSS, TDS, hardness, total organic carbon (TOC), acidity and cyanide (CN), while a subset of nine locations were sampled for biological oxygen demand (BOD), and ammonia (NH_3).
- June 2000: 32 locations were sampled for total metals, alkalinity, TSS, TDS, hardness, and acidity (Contracted Laboratory sample handling errors resulted in a lack of confidence for several June-event samples).
- July 2000: 46 locations were sampled for total and dissolved metals and cyanide, while 41 locations were sampled for alkalinity and anions (negatively charged ions),

42 sampled for hardness, 11 sampled for BOD, Total Kjeldahl Nitrogen (TKN), and NH_3 , and 10 were sampled for VOCs, polychlorinated organic compounds (PCBs), pesticides, and Base Neutral Acids (BNA).
- September 2000: 49 locations were sampled for total and dissolved metals 35 locations for alkalinity, 34 locations for hardness and acidity, 13 locations for CN, and five locations for BOD, TKN, and NH_3.
- October 2000: 17 locations were sampled for total metals and hardness.
- November 2000: 17 locations were sampled for total metals and hardness.
- December 2000: 17 locations were sampled for total metals and hardness.
- January 2001: 16 locations were sampled for total metals and hardness.
- April 2001: 6 locations (2,4,6,7,8,25) sampled for total and dissolved metals plus field parameters
- May 2001: 43 locations were sampled for total and dissolved metals and hardness.
- September 2001: 56 locations were sampled for total and dissolved metals and hardness.

Previous investigations by the State of Vermont, federal agencies, or local organizations include the following:

- The Vermont Agency of Environmental Conservation (1977) sampled 10 locations spaced above, around, and below TP-1, as well as on the Ompompanoosuc River, for analysis of 10 metals.
- Colorado School of Mines (COSOM, 1984) sampled 16 locations around the Site and in the Ompompanoosuc River at the Union Village Dam. Samples were analyzed for metals plus pH.
- USACE generated a report in 1984 entitled, “Union Village Dam Water Quality Evaluation Update,” Army Corps of Engineers Hydraulics and Water Quality Section, Water Control Branch, Engineering Division. This report provided surface water sample results from 1971 through 1983 for five stations on the Ompompanoosuc River. The primary metals of concern were copper, aluminum, iron, cadmium, mercury, and zinc.
- In August of 1990, the Vermont Agency of Natural Resources (VTANR, 1990) sampled surface water for a core group of metals plus pH at three locations:
  - SW-1 - Between TP-2 and TP-3
  - SW-2 - Background stream that flows in from east
  - SW-3 - Copperas Brook before confluence with the WBOR
  - GW-3 - Air Vent
- During April and August of 1998, approximately 35 locations were sampled by the USGS around the Elizabeth Mine Site as well as locations upstream and downstream on the Ompompanoosuc River (USGS, 1998). Most of these locations were in and around TP-1. This study included an extensive list of metals as well as water quality parameters.

- The Elizabeth Mine Study Group (EMSG, 1999), along with Step by Step, Inc. and Damariscotta, sampled locations for a core group of metals and pH at three locations:
  - H1 - Drainage pipe at eastern corner of TP-1
  - H2 - Western tributary to Copperas Brook below TP-1
  - H3 - Between TP-2 and TP-3

1.6 Source, Nature, and Extent of Contamination

A number of distinct contaminant source areas have been identified at the Elizabeth Mine Site. The three tailing and mine waste piles located in the Copperas Brook watershed are source areas 1 through 3:

- TP-1 – 30 acre area
- TP-2 – 5 acre area
- TP-3 – 12 acre area

A fourth contaminant source area is a continuous discharge of ground water from the underground workings, referred to as the “air vent”. The air vent connects the underground workings (200 feet below the ground surface) with the surface at a location nearly one mile north of the main open cuts, adjacent to the WBOR. The fifth and sixth identified source areas are the South Open Cut and the South Mine waste rock pile, each located south of the North Cut and situated along the crest of Copperas Hill ridge in the Lord Brook watershed. This report addresses contamination associated with TP-1, TP-2, and TP-3. The air vent, South Mine, and South Open Cut sources, as well as any other potential source areas, will be addressed as part of the RI/FS.

1.6.1 Tailings and Waste Rock

The principal tailings piles located at the Site (TP-1 and TP-2) were generated through sulfide ore milling operations through the 1940s and 1950s. These two waste piles are wedge-shaped, with the thickest sections situated along the down-slope, north-facing sides. TP-1 is approximately 30 acres in area, and has a maximum thickness of approximately 110 feet; TP-2 is approximately five acres in area and has a maximum thickness of approximately 35 feet. Directly underlying TP-1 and TP-2 is the thin layer of gravel and debris from the pre-tailings ground surface.

TP-1 and TP-2 are composed of crushed and processed ore that is a fine sand/silt-sized material. The minerals jarosite and goethite dominate the oxidized surface of the tailings. During July/August 2000, samples of the upper oxidized material were collected and analyzed for metals concentrations and for grain-size distribution by the USGS. Fine-grained sand constitutes more than 50% (by weight) of the surface material in the areas surrounding piezometers #4 and #5 (see Figure 1-2 for the piezometer locations and particle size analysis results). Below this oxidized zone, the tailings consist of a tightly-compacted black anoxic silt/fine sand. There appears to be some (minor) vertical differentiation throughout the pile, with a thin clay-rich accumulation layer in several borings at a depth of several inches to one foot below the tailings surface.

TP-1 and TP-2 are representative of a class of tailings impoundments described by Davies and Martin (2000) as “upstream tailings dams” The tailings impoundments started with an earthen dam constructed at the toe of the impoundment and tailings were deposited from down-slope (downstream) to up-slope (upstream). This approach resulted in wedge-shaped tailings pile, where the down-slope edge is topographically higher than the up-slope edge. By depositing tailings slurry from the down-slope side, coarser sandy material created a dry beach at the down-slope edge and finer materials were transported by gravity and deposited in a settling pond within the upstream interior of the pile. Today, a decant tower for the interior settling pond can be observed on the surface of TP-1. The decant tower and drainage system for TP-2 has collapsed and eroded.

A volume analysis of TP-1 and TP-2 was completed by comparing the 1896 USGS topographic data to the recent (spring 2000) topographic surveys. The 1896 data was calibrated using the borehole information as a guide. From this analysis, the total volume of the combined TP-1 and TP-2 was calculated to be approximately two million cubic yards.

TP-3 has a very irregular surface, with thickness ranging from several feet to more than 40 feet. TP-3 is divided into several subareas on the basis of historic operations and the relative percent of unoxidized sulfide material present. Colorful piles of variably pyrolyzed sulfide ore are present over an area of approximately six acres in the center of TP-3, representing “heap leach” residues from the production of copperas (iron sulfate) throughout the 1800s. Bright orange-red hematite-rich piles represent thoroughly pyrolyzed (roasted) massive sulfide. Yellow limonite and jarosite-rich rock represents waste material (deposited on top of the copperas heap leach piles) from later phases of copper mining. Adjacent to the North Open Cut, especially toward the southern end of the cut, low-sulfide content waste rock piles are mixed in with the sulfides used for copperas production. Given the nature of the materials present, TP-3 should not be referred to as “tailings”; however, the TP-3 nomenclature has meaning to most local citizens and site investigators. Therefore, for consistency, this area will be referred to as TP-3 in this report.

The USGS sampled and analyzed portions of TP-3 in 1998 (Hammarstrom, 1999). The USGS divided TP-3 into six subareas (A-F) based on differences in surface color and texture (see Figure 1-3 for the subareas defined by the USGS). Paste pH composite samples were measured in the field, and samples were analyzed for mineralogy and chemistry. Physical characteristics, paste pH and dominant minerals determined by x-ray diffraction (XRD) are listed in Table 1-1. Colors were determined on dry materials by comparison with Munsell soil color charts. These data show that the red piles of the old (copperas) workings (TP-3) are hematite-rich and have slightly higher paste pH values than the adjacent jarosite-rich piles. Weathered ore and waste-rock litters the upper parts of TP-3. After periods of dry weather, white coatings of efflorescent iron sulfate salts cover sulfide-rich cobbles and boulders, creating a “snowball” appearance. The minerals halotrichite, melanterite and rozenite (copper/iron/aluminum salts) wash away with each rainstorm event. The mineralogy and spatial distribution of minerals in TP-3 are important from the standpoint of acid-generation potential. Detailed mapping and analysis of acid-generation potential across TP-3 will be accomplished during the design and/or RI/FS.

Selected metal concentrations from chemical analysis of the USGS samples are listed in Table 1-2 along with reference soil values (mean concentrations of elements in eastern U.S. soils). Analytical methods and detection limits are given in Hammarstrom (1999). Hammarstrom (2000) noted that these data lead to several conclusions that should be factored into remedial plans:

- Copper and zinc concentrations in all types of mine waste on the Site are elevated and exceed critical values for acute toxicity for plants; these elevated metal concentrations and the acidity of the surface material probably account for the lack of success of revegetation (planted by volunteers) and the stunted appearance of the vegetation that has established itself on parts of the flat tops of TP-1 and TP-2.
- Metal concentrations in the older waste piles (TP-3) are an order of magnitude (ten times) higher than in TP-1 and TP-2.
- A number of potentially toxic metals, such as mercury, lead, cadmium, and arsenic are present (generally at low concentrations) in waste materials at the Site.

More information regarding the Geology and Geochemistry can be found in Appendix G which contains USGS Guidebook Series Volume 35 Part II. Environmental Geochemistry and Mining History of Massive Sulfide Deposits in the Vermont Copper Belt (USGS, 2001).

1.6.2 Soil Contamination

Surface soil samples were collected from three residences located along Mine Road near the Elizabeth Mine Site in July and November 2000. Each sample was analyzed for metals through the EPA Contract Laboratory Program (CLP). Sample analytical results are provided in Table 1-3, along with risk-based concentrations from several sources and local surface soil background data provided by EPA. The soil data revealed a few instances where levels of iron, lead, and thallium warrant further study as part of the RI/FS for the Site, because levels were greater than background. The concentrations of these contaminants were not at levels considered to represent an acute (short-term) hazard. The Agency for Toxic Substances and Disease Registry (ATSDR) confirmed EPA’s assessment that the residential soil data do not indicate any current risks that would warrant immediate EPA action. All of the soil data has been transmitted to the residents and the Vermont Department of Public Health. A more detailed evaluation of the soil data will be presented in the Baseline Human Health Risk Assessment, prepared as part of the RI/FS. Appendix H presents the ATSDR Health Consultation Reports.

1.6.3 Ground Water Contamination

Ground water studies to date are limited to samples from residential wells along Mine Road and water level measurements from piezometers within and adjacent to the tailings piles. Ground water quality information is available from nine residential wells located along Mine Road, west of TP-1 and TP-2 (EPA 2000 and 2001 sampling program). The concentrations of chemicals detected in drinking water are compared with the health-based primary Maximum Contaminant Levels (MCLs), secondary MCLs (EPA, 1991, 1992), and with the Vermont Health Advisories (VHAs) (VT Department of Health, 1998) in Table 1-4. Figure 1-4 shows the residential locations in relation to the tailings piles.

Drinking water from one former residence, situated at the edge of TP-3, exceeded criteria for copper, cadmium, aluminum, and sulfates. The resident re-located and the well is no longer used. None of the other residential wells sampled, nor the monitoring well installed adjacent to TP-3 indicate an adverse impact to groundwater by the mine.

To evaluate the nature of ground water flow within the tailings, nine piezometers were installed through the tailings in July/August 2000. The piezometers were developed and allowed to equilibrate with local pore pressures. Monthly piezometer monitoring data (piezometric head) were collected for both the tailings and the till (see Figures 1-5 and 1-6). The measurements collected to date reflect summer, fall, and winter conditions. Ground water elevations did not fluctuate significantly between the sampling events, suggesting a hydraulic dampening effect within the tailings that masks the impact of individual storm events. More data is needed to evaluate the seasonal impact on the ground water from precipitation and infiltration, particularly in the spring.

Measurements within and below TP-1 and TP-2 indicate that ground water flow is toward the north-northwest, generally following the pre-tailings surface topography (see Figure 1-7). Nested piezometer couplets indicate that there is a slight downward vertical gradient throughout TP-1 and TP-2. Hydraulic conductivity and porosity have not been determined at this point. The information gathered to date indicates that the basal till underlying TP-1 and TP-2 is a low-yield, nearly impervious geologic material of considerable thickness overlying bedrock. The thin, irregular water-bearing unit between the tailings and till does not appear to be a significant ground water resource, but it may be a preferred hydraulic pathway for minor lateral flow and recharge to the base of the tailings. The downward vertical gradient present during the summer, fall, and winter months suggests, however, that any recharge to the tailings from below is limited.

Recharge of ground water within the tailings material in TP-1 and TP-2 is largely influenced by surface water infiltration. At present, ground water infiltration and transport related to the decant tower and the geologic units below the tailings is not well documented. Further investigation is necessary to evaluate the significance of these features. Several ground water seeps are observed (year-round) at the toe of TP-1, with fewer seeps at the toe of TP-2. Individual seep flow is as much as 15 to 20 gallons per minute (gpm). Flow rates for most seeps do not appear to vary significantly on a seasonal basis, suggesting that the tailings pile "dampens" any seasonal or episodic rain or snowmelt event. TP-1 seep data is presented in Appendix F.

A concrete diversion culvert, once situated below TP-2, has completely eroded, resulting in direct discharge of the upper reach of Copperas Brook onto the surface of TP-1. This has resulted in a year-round surface pond, measuring one to two acres, on the top of TP-1. A similar concrete decant tower remains in place below TP-1, to channel Copperas Brook flow from the pond back into the natural drainage channel at the foot of TP-1.

A piezometer situated in TP-3 indicates the presence of a near surface unconfined water-bearing horizon above the bedrock and a second saturated zone within the highly fractured bedrock. Depth to bedrock at TP-3 is approximately 12 feet below ground surface. The piezometer (nested-pair, representing different hydraulic zones) indicates that a significant upward vertical gradient is present between the two water-bearing zones in this area. Recharge to the bedrock aquifer is likely through a combination of precipitation/infiltration and flooded underground workings. The horizontal gradient in the TP-3 area, while not known at this time, is likely significant and follows the natural topography.

1.6.4 Surface Water and Sediment Contamination

To assess the extent of environmental impact from the Elizabeth Mine, EPA collected surface water and sediment samples throughout the Elizabeth Mine area, within the WBOR watershed. Sample locations are broadly divided into the following nine groupings (see Figure 1-8 and Tables 1-5 and 1-6):

- *WBOR upstream of Mixing Zone* includes the WBOR upstream from the Air Vent and Copperas Brook
- *Unaffected tributaries to the WBOR* include Sargent Brook, Abbott Brook, Fulton Brook, Jackson Brook, Bloody Brook, and lower Lord Brook
- *Air Vent Mixing Zone* includes locations within the WBOR between the Air Vent and the confluence with Copperas Brook – approximately 2,500 feet in length
- *Contamination Source Areas* includes location within the Copperas Brook watershed and the Air Vent prior to discharge into the WBOR
- *WBOR Mixing Zone* include the section of the WBOR from Copperas Brook confluence to a point approximately 2500 feet downstream
- *WBOR Below Mixing Zone* includes the stretch of WBOR between the East Branch of the Ompompanoosuc River (EBOR)/WBOR confluence and EPA sample location No. 42

- *Affected tributaries to the WBOR* include upper Lord Brook, two intermittent streams on Mine Road, and an intermittent stream within the Copperas Brook drainage
- *EBOR*
- *Ompompanoosuc River below confluence of EBOR and WBOR*

For surface water, fifteen contaminants were detected at concentrations above Vermont Water Quality Standards (VTWQS) or EPA criteria, including: aluminum, barium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, manganese, selenium, silver, thallium, vanadium, and zinc. VTWQS are available for cadmium, chromium, copper, cyanide, iron, lead, selenium, and zinc. EPA used reference material (EPA, 1996, EPA, 1999, Suter, 1996) to establish the criteria used in this report for aluminum, barium, cobalt, manganese, silver, thallium, and vanadium. Sample data from the 2001 sampling event were not available at the time of report (EE/CA) preparation.

Nine of these 15 contaminants appear to be clearly related to the source material based on their concentration and frequency of occurrence in the Source Area samples: aluminum, cadmium, cobalt, copper, iron, manganese, selenium, silver, and zinc. Six of these metals (aluminum, cobalt, copper, iron, manganese, and zinc) represent the bulk of the risk and have been designated as the primary Contaminants of Concern (COCs). The remaining three from the subset of nine contaminants believed to be Site related (cadmium, selenium, and silver) as well as the other six contaminants detected above reference criteria (barium, chromium, cyanide, lead, thallium, and vanadium) warrant further evaluation as part of the RI/FS to determine if they are Site-related, based on concerns regarding data quality, frequency of occurrence, and/or naturally occurring background levels. Table 1-7 presents the fifteen contaminants of potential concern, and highlights the list of contaminants designated as COCs for the purposes of this report. Detailed findings from the surface water investigation are discussed below (see Section 1.7, Streamlined Risk Evaluation).

Two sediment-sampling events were completed in 2000 and one in 2001. The first was completed in July 2000 and the second in September 2000. The 2001 sediment-sampling event was also conducted in September, along with a synoptic surface water-sampling event. In July 2000, 41 locations were sampled for total metals, acid volatile sulfide/simultaneously extracted metals (AVS/SEM), grain size, and TOC. One location was sampled for cyanide, and five locations were sampled for VOCs, SVOCs, pesticides, and PCBs. In October 2000, 11 of the 41 locations were sampled for total metals and AVS/SEM. In September 2001, 35 locations were sampled for sediment, including eight samples in the “mudflat” area at the confluence of the Ompompanoosuc and Connecticut Rivers. Findings from the sediment-sampling program are described below (see Section 1.7, Streamlined Risk Evaluation).

Appendix D contains a summary of surface water and sediment data from select sampling locations as well as summary statistics for physiographic areas.

1.6.5 Conceptual Site Model

The three source areas under evaluation in this EE/CA are located in the Copperas Brook watershed, that drains into the WBOR, approximately six miles upstream from its confluence with the EBOR, near the Union Village dam. The Ompompanoosuc River empties into the Connecticut River approximately three miles downstream of the Union Village Dam. Copperas Brook flows from its headwaters near TP-3 over a distance of nearly one-mile to its confluence with the WBOR. Figure 1-9 provides a summary of the key elements of the Conceptual Site Model, Copperas Brook watershed, including the significant mine features. The Site conceptual model incorporates all of the major source areas and drainage features observed in this figure.

Upper Copperas Brook originates a short distance from the base of TP-3 and flows through a divide in TP-2 onto the surface of TP-1, where it enters a small pond (a former settling pond for tailing fines). A decant tower diverts water from the surface of TP-1 through a concrete pipe, to a discharge point at the northeast corner of the tailings pile. Water from the pipe combines with ground water discharge seeps from the base of TP-1 to form Lower Copperas Brook in the wooded areas and wetlands below the tailings.

The Copperas Brook watershed is approximately 300 acres in size, has an overall vertical drop of approximately 750 feet, and a flow range of approximately 25 gpm to over 2000 gpm at the confluence with the WBOR (EPA Sample Location 6). The upper portion of the watershed normally experiences low flows in summer months, in the range of less than 2 gpm to 10 gpm at EPA's sample Location Number 2 (below TP-3). Spring flow and storm events result in substantially higher flow. Spring flows have been measured at 76–360 gpm. Storm event flow of over 300 gpm has been measured at the Location 2 gauging station. Mid-winter (February) flow of approximately 5 gpm has been observed by EPA at this location.

TP-3 sits primarily on bedrock or a thin veneer of overburden material. TP-1 and TP-2 appear to be underlain by a thick glacial till of very low hydraulic conductivity. Although a thin sand unit has been found between the tailings and the till, it is believed that the till layer limits the flow of ground water into the tailings. Surface water/ground water modeling by the USGS (Harte, 2001; *Personal Communication*) suggests that approximately 80-90% of the water within the tailings results from surface water and shallow groundwater run-on from upper Copperas Brook; the remaining 10 to 20% is provided mostly by direct precipitation and snowmelt with a small component of flow from deep ground water.

Acid conditions in surface water are generated by the interaction of waste sulfide minerals (pyrrhotite, pyrite, and chalcopyrite) with water and oxygen. The oxidation of sulfides exposed to natural weathering conditions produces acid, which in turn dissolves metals such as copper, zinc, aluminum, and cadmium. Copperas Brook acquires most of its load of metals and acidity in the TP-3 area. Rain water and ground water discharged within the Copperas Brook watershed transport metals, acidic water, and tailings fines to the WBOR, where impacts to biological communities and water/sediment quality have been observed and recorded by EPA and others. The acidity of Copperas Brook averages around 650 milligrams per liter of calcium carbonate equivalent. The reference portion of the WBOR, upstream of the air vent and confluence with Copperas Brook, has an average alkalinity around 100 milligrams per liter of calcium carbonate equivalent. Under present conditions, 6.5 gallons of surface water from the WBOR are needed to neutralize the acidity contributed by each gallon of water from Copperas Brook.

1.6.6 Site Physical Characteristics That Impact Alternative Evaluation

The following physical characteristics affect the evaluation of cleanup alternatives:

1. The tailings and waste materials are located within a steep drainage in the headwaters of the Copperas Brook watershed. Minimal water storage exists in the upper portion of the basin. Consequently, the watershed displays a wide range in surface water flows due to seasonal conditions and rainstorm events. Because of the lack of significant surface water attenuation (infiltration), cleanup alternatives must be designed to address both the longer-term (minimal) flow rates and the occasional peak storm and snowmelt runoff events.
2. There are stability issues associated with all of the tailing piles and bedrock beneath TP-3. Long-term structural stability is a critical factor. The stability of all tailings piles is reduced when rain, snowmelt, or other conditions result in saturation of the waste material.
3. There is limited space in some areas of the Site to perform the anticipated response actions, due to the presence of historic resources.
4. The flow of ground water within the tailings remains uncertain. Long-term response and remedial actions at the Site must account for discharges of seep water through the base of tailings. Most response actions under consideration will significantly reduce the flow at the seeps of TP-1 and TP-2 over the long-term.
5. The natural soils below TP-1 and TP-2 appear to be glacial tills with very low water yielding potential. This limits the ability of the natural system to attenuate peak flows. This layer of glacial till may be used to “key-in” excavated diversion channels to limit flow into the tailings.
6. Most of the tailings material is situated above the natural water table elevation. The bottom of the tailings is currently saturated above the original ground surface. The water level within the tailings appears to be a result of constant infiltration from rain events, discharges from Upper Copperas Brook, and seasonal snowmelt.

1.7 Streamlined Risk Evaluation

Since April 2000, EPA has gathered and analyzed information from the Elizabeth Mine Site to characterize the nature and extent of contamination and associated risks to human health and ecological receptors from waste materials and the mine workings. Surface water and sediment samples have been collected on a regular basis at sampling stations throughout the WBOR. Residential soil, drinking water, and dust samples have been collected from nearby homes to assess potential Site-related risks.

A detailed Human Health Risk Assessment (HHRA) will be performed as part of the RI/FS. Both EPA and ATSDR have completed an evaluation of the data collected to date and have determined that there is no immediate risk to local residents. Appendix H presents the ATSDR Health Consultation Reports. This determination is based on monthly residential drinking water sampling at a number of residences in the immediate mine area. Initial monthly sampling targeted nine residences; the number of homes sampled on a regular basis was reduced as it became clear that no exceedances of drinking water criteria were found beyond a single home located adjacent to TP-3.

A streamlined ecological risk evaluation was completed to provide an assessment of the likelihood of Site-related effects on certain receptors. This assessment is based on surface water and sediment samples, sediment toxicity tests, benthic community surveys, algae surveys, and fish community surveys. The primary concern at the Site is the AMD resulting from surface water interaction with mine tailings and waste rock piles. For a distance of approximately five miles below the confluence of Copperas Brook with the WBOR, concentrations of metals in surface water exceed applicable Vermont and EPA numerical standards.

1.7.1 Ecological Risk Assessment

The streamlined ecological risk assessment followed a two-step approach to the development of the risk characterization. The first step involved evaluation of chemical data to determine which of the chemicals found in the surface water and sediments are Contaminants of Concern (COCs). The second step involved the use of biological measures of impact, including toxicity testing, fish community surveys, and benthic organism community surveys. The VTWQS consist of both numerical (chemical) and biological criteria to assess compliance with the standards.

The streamlined risk assessment is organized as follows:

- Identification of General Ecological Receptors (Section 1.7.1.1)
- Potential Contaminant Migration Pathways (Section 1.7.1.2)
- Data (Section 1.7.1.3)
- Selection of Contaminants of Concern (COCs) (Section 1.7.1.4)
- Conclusions from Streamlined Ecological Risk Evaluation (Section 1.7.1.5)

1.7.1.1 Identification of General Ecological Receptors

The WBOR, Copperas Brook, and affected tributaries provide habitat for various aquatic receptors, including fish, benthic organisms, macroinvertebrates, plankton, and algae. These receptors in turn likely support piscivorous or omnivorous birds (e.g., kingfishers, herons, ducks) and mammals (e.g., river otter, mink, raccoon). A complete characterization of potential ecological receptors at the Elizabeth Mines Site, based on surveys by professional ecologists or wildlife biologists, will be performed during the process of completing the full Baseline Ecological Risk Assessment (BERA) for the Site.

1.7.1.2 Potential Contaminant Migration Pathways

Surface water and sediment transport contaminants from source areas to ecological receptors. Two recent reports, *Elizabeth Mine Site Conditions Report* (ADL, 2001) and the *Summary of Preliminary Ecological and Human Health Risk Evaluations* (ADL, 2001) provide an overview of the contaminant migration and exposure pathways. As Copperas Brook runs directly through the tailing piles/waste-rock piles, COCs contained in these materials can migrate directly into Copperas Brook. Copperas Brook flows directly into the WBOR. A second contaminated tributary to the WBOR, Lord Brook, is situated in a separate watershed directly south of the Copperas Brook and is contaminated by mine-related waste materials from the South Mine and South Open Cut. Contaminants may leach from the tailings pile/waste heaps into ground water and discharge into the river. The air vent discharges contaminated water directly to the WBOR from the underground mine workings.

Sampling has shown that concentrations of COCs in surface water and sediment of Copperas Brook, the WBOR, and affected tributaries are significantly higher than both appropriate benchmarks and concentrations at nearby (upstream) Reference locations. Therefore, receptors that frequently come in contact with sediment or surface water, or those that reside further up on the food chain and consume aquatic receptors that have taken up COCs, may be impacted. Preliminary investigations have demonstrated impacts on benthic organisms, fish, and algae.

1.7.1.3 Presentation of Data

Surface Water. The surface water data collected since April 2000 indicate that 15 contaminants are detected at concentrations above VTWQS or EPA criteria, including: aluminum, barium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, manganese, selenium, silver, thallium, vanadium, and zinc. Nine of these metals appear to be related to the mine waste source material based upon concentration and frequency of occurrence (aluminum, cadmium, cobalt, copper, iron, manganese, selenium, silver, and zinc). The remaining contaminants (barium, chromium, cyanide, lead, thallium, and vanadium) warrant further evaluation during the RI/FS.

Six of the nine Site related contaminants (aluminum, cobalt, copper, iron, manganese, and zinc) have been designated as COCs in surface water. Table 1-8 summarizes the Hazard Quotients (HQs) and Hazard Indices (HIs) for the relevant samples. A summary of surface water results is provided in Figure 1-10.

The levels of contaminants detected in the surface water of Copperas Brook and the Mixing Zone of the WBOR are many times higher (as indicated by the HQs) than the relevant criteria - one to three orders of magnitude, or tens to thousands of times higher. A decrease in metals concentrations is observed in the WBOR with distance downstream of the Copperas Brook confluence. Copper is the only COC to remain significantly above upstream concentrations beyond the Union Village Dam at EPA Location 44. The following is a summary of key findings from the surface water quality studies conducted by EPA:

- Concentrations of aluminum, cadmium, chromium, cobalt, copper, iron, manganese, silver, and zinc in the Source Area are substantially higher than VTWQS, other EPA accepted criteria for surface water, and the upstream (Reference) areas.
- Six of these contaminants (aluminum, cobalt, copper, iron, manganese, and zinc) are also detected at concentrations above VTWQS and EPA accepted criteria well past the confluence of the WBOR and Copperas Brook.
- Copperas Brook and a section of the WBOR just below the confluence with Copperas Brook have the highest concentrations of metals in surface water within the study area.
- HQs for copper, iron, aluminum, and zinc are significantly higher (one to three orders of magnitude, or 10 to 1,000 times higher) in the Source Area and Mixing Zone than in upstream (Reference) areas; the corresponding HIs show similar trends.
- Maximum concentrations of metals in the WBOR within the Mixing Zone area exceed applicable criteria (VTWQS or other EPA criteria) by a factor of 201 for aluminum, 9 for cobalt, 63 for copper, 50 for iron, and 17 for manganese.
- Although aluminum is consistently elevated in upstream locations, the levels found in the Source Areas and Mixing Zone are substantially higher than the concentrations detected at upstream locations.
- The point at which the WBOR completely recovers to VTWQS numerical criteria is not known. Elevated metals concentrations have been sporadically detected at the furthest downstream surface water sampling station, below Union Village Dam.

Sediment. Samples of sediment were collected at each surface water sampling location, and several additional locations and submitted for metals analysis during two sampling events (June and September/October 2000). The HIs results for sediment samples are summarized in Table 1-9. A summary of sediment results is provided in Figure 1-10. Concentrations of copper, iron, manganese, and zinc are higher in the Source Areas and the Mixing Zone Area than upstream (Reference) levels. Copperas Brook and a section of the WBOR just below the confluence with Copperas Brook have the highest concentrations of metals in sediment within the study area. Aluminum, iron, and zinc concentrations in sediments do not display the strong Site-related pattern observed for copper. HQs and associated HIs for metals below the confluence of the EBOR and the WBOR are comparable to the Mixing Zone, suggesting that little to modest attenuation of metals contamination in sediment occurs with increasing distance from the Source. The HI for the Air Vent Mixing Zone was not greater than the upstream areas, suggesting that the air vent may not represent significant metals loading to the sediments or that the Air Vent loading is transported downstream due to scour and re-deposition. The following is a summary of key findings from the sediment studies conducted by EPA:

- Concentrations of copper, iron, manganese, and zinc are higher in the Source Areas and Mixing Zone Area than upstream (Reference) levels.
- Copperas Brook and a section of the WBOR just below the confluence with Copperas Brook have the highest concentrations of metals in sediment within the study area.
- Maximum concentrations of metals in the Mixing Zone Area of the WBOR exceed applicable criteria by a factor of 11 for copper, two for iron, two for manganese, and are slightly above the criteria for zinc.
- HQs for copper and iron are much higher in the Source Area and Mixing Zone than in the Upstream of Mixing Zone Area; the corresponding HIs show similar trends.
- Elevated levels of copper (130 mg/kg), resulting in a HQ of six, have been detected below Union Village Dam, as far as the Connecticut River at EPA Location 38.

The surface water and sediment data document severe impact to Copperas Brook and a section of the WBOR as a result of the discharges from the Source Areas. All of Copperas Brook and a section of the WBOR fail to meet numerical VTWQS for several metals on numerous sampling occasions. In addition to the evaluation of the chemical data (described above), several lines of biological evidence were examined to determine the potential for significant impacts. These lines of evidence are summarized below.

Surface Water and Sediment Toxicity Tests. Toxicity tests were conducted to evaluate the effect of exposure to surface water and sediment from the Site on aquatic invertebrates and fish (fathead minnow, amphipod [scud], bloodworm, and water flea). Toxicity tests evaluate cumulative effects of chemicals by introducing healthy organisms to Site surface water and sediment for a specific time period. For comparison, the same types of organisms were exposed to upstream (Reference) area surface water and sediment over the same test period. Two rounds of toxicity testing were performed, corresponding to the June and September 2000 EPA sampling events. The results of the toxicity tests are shown in Figures 1-12 and 1-13. The results of the toxicity testing indicate that Source Area surface water and sediment is toxic to tested organisms. Nearly 100% of the organisms died as a result of exposure to the surface water and sediments from the Source Area. The Copperas Brook surface water was so toxic that even when it was substantially diluted (to levels as low as 10% of the original sample) with clean water, the test organisms died. All test organisms also died from exposure to surface water from sample Location 8 (air vent discharge) and Location 12 (within WBOR just downstream of confluence with Copperas Brook). Location 13 (within the WBOR, near the Copperas Brook confluence) showed similar toxic results in the sediment toxicity tests. The following is a summary of key findings from the toxicity tests performed by EPA:

- When exposed to surface water of Copperas Brook, the air vent, or the Mixing Zone of the WBOR, nearly all test organisms died (no test organisms survived in three tests and only 10% survived the fourth test).
- When exposed to the sediment of Copperas Brook or the section of the Mixing Zone Area near the confluence at EPA Location 13, nearly all organisms died.
- The sediments at locations:Upstream of Mixing Zone, Air Vent Mixing Zone, lower section of Mixing Zone, and Below Mixing Zone Areas did not show toxic effects to test organisms.
- Growth, survival, and reproduction of all organisms tested with water from the Air Vent Mixing Zone were comparable to the Reference Area results.

Benthic Organism Community Assessment. Species diversity and density of benthic organism populations are other key measures of the health of the river environment assessed in this study. Species density and diversity are severely depressed in Copperas Brook, the Mixing Zone, and Affected Tributaries. When compared to the VTWQS, the WBOR does not meet biological standards for three criteria (Density, Taxa Richness, and EPT Richness) for a stretch extending from the confluence with Copperas Brook to approximately 5 miles downstream of the confluence with Copperas Brook, near EPA location 29. Complete recover to the upstream (Reference) conditions is not observed until EPA location 44, at the Union Village Dam. The WBOR, however, does achieve VTWQS for two or the three measures by EPA Location 19, just upstream of Rice's Mills. Figures 1-14 and 1-15 show the results for the benthic epifauna survey. Statistical projections (plot of abundance and richness over distance from source) confirm that the VTWQS for all criteria should be met on the stretch of the WBOR near Union Village Dam. Figure 1-16 shows the statistical results. The samples of the benthic community in the section of the WBOR within the Air Vent Mixing Zone are similar in most respects to the upstream (Reference) Area and Ompompanoosuc River (below EBOR and WBOR confluence) samples. These results indicate that the air vent contribution to the WBOR contamination is not significant in terms of biological impact, even though water chemistry results indicate the potential for impacts to the aquatic organisms in this stretch of the river.

Figures 1-17 and 1-18 show the results of the benthic infauna survey. While there are no VTANR criteria for infauna, a general comparison of abundance and diversity can be made between locations upstream and downstream of Copperas Brook. The infauna results also suggest severe impact in the Source Area and Mixing Zone, with levels returning to normal downstream of the Mixing Zone. A summary of the VTANR assessment of the benthic studies is attached in Appendix E. The following is a summary of key findings from the benthic community surveys conducted by EPA:

- The density and diversity of benthic water-dwelling species (epifauna) within the Mixing Zone are significantly lower than in the upstream (Reference) area.
- The density of sediment-dwelling organisms (infauna) is impaired within the Mixing Zone; however, infauna diversity within the lower reaches of the Mixing Zone is similar to the upstream (Reference) area.
- A VTANR assessment of the benthic data collected in 2000 and 2001 resulted in a determination that a one-mile section of the WBOR below the confluence with Copperas Brook was severely impaired and in generally poor condition with another 3.7 miles in fair condition, but not meeting VTWQS.
- Source Area samples show extremely low organism density and little diversity.
- Sediment-dwelling organism (infauna) density in the Source and Mixing Zone locations show little difference when compared with the upstream (Reference) area. This may be due to the limited sediment habitat within the WBOR.

Fish Abundance Surveys. Fish density and diversity are key measures in the evaluation and analysis of impacts to the WBOR and affected tributaries. Studies by the USACE (1990), VTANR (1987 and 2000), and EPA/VTANR 2001 provide a basis for an assessment of contamination effects on fish communities. The fish study results from earlier studies are provided in Figure 1-19. A summary of the VTANR assessment of the September 2001 fish sampling is attached as Appendix E.

All three fish surveys provide evidence that the AMD from the Elizabeth Mine is having a severe impact on the fish communities in certain sections of the WBOR and its affected tributaries. The studies show that the density of the forage species upstream of the mine was more than three times higher than density at the downstream locations. VTANR calculated an Index of Biotic Integrity (IBI) value for these stations. IBI measures ecological health of the fish community as a whole. Figure 1-19 (top plot) presents IBI as well as fish density for the USACE and VTANR data. The IBI in the upstream areas of WBOR is 39 (as compared to the VT threshold values for Class B waters of 29 to 31), whereas the IBI for the WBOR below Copperas Brook is only nine. A study conducted by the VTANR in the tributaries of WBOR (Langdon, 2001) noted more than a ten-fold reduction of fish density in Lord Brook downstream from the South Open Cut source area, as compared with a stretch of Lord Brook upstream of the South Open Cut source. No fish were found in Copperas Brook. Langdon concluded that the impact of toxic levels of metals is likely to be responsible for the low density of fish in these areas. The following is a summary of key findings from the fish surveys conducted by VTANR and USACE:

- The USACE 1990 study of the WBOR found the biomass (total weight of fish within a given area) and density of the forage species (dace, sculpin, and sucker), which are indicative of ecological damages, are severely affected. The biomass and density downstream of the mine were about three times lower than similar characteristics of the upstream reference areas.

- The VTANR studies (1987, 1998, and 2000) found even more severe detrimental effects of contaminants originating from the mines on fish communities in the tributaries of the Ompompanoosuc River. No fish were found in Copperas Brook. The fish density in the affected areas of Lord Brook was almost 10 times lower than fish density in unaffected areas of Lord Brook and Sargent Brook.
- The IBI as a whole was found to be depressed significantly from a value of 39 in the upstream areas of the WBOR (as compared to the VT threshold values for Class B waters of 29 to 31) to a value of nine (well below the WQS threshold) in the downstream areas affected by the mine.
- The degradation of fish community health identified in the USACE 1990 and VTANR 2000 studies was confirmed by the EPA/VTANR 2001 studies.
- The fish surveys indicate that a section of the WBOR extending between 0.8 and 1.3 miles downstream of the confluence has been impacted such that VTWQS (biological measures) are not met.

1.7.1.4 Selection of Contaminants of Concern (COCs)

COCs were selected based on the following:

- The geographic extent of contamination as measured by the percent of samples in which chemical concentration was found to exceed applicable regulatory standards, and
- The magnitude of contamination as measured by chemical-specific HQs.

The HQ is the quotient of the Site contaminant concentration divided by the acceptable (“safe”) concentration, or, in other words, the number of times by which the contaminant exceeds the acceptable level. The HQ method was used to identify COCs and calculate potential ecological risks from metal contaminants for each of the nine general Site areas/data groupings (e.g., Source Area, Mixing Zone, etc.). The numerical VTWQS were used as the safe level, when available. Several constituents in surface water did not have a VTWQS. For these instances, EPA identified appropriate criteria from available literature (EPA, 1996, EPA, 1996, Sutter, 1996). There are no Vermont standards for sediment; therefore, all of the safe levels for sediments were from EPA accepted sources. Table 1-10 lists the criteria used as the safe level in calculating the HQs in surface water and sediment.

Table 1-7 presents the fifteen contaminants of potential concern, and highlights those *six* contaminants designated as COCs (aluminum, cobalt, copper, iron, manganese, and zinc) for the purposes of this NTCRA.

1.7.1.5 Conclusions from Streamlined Ecological Risk Evaluation

Figure 1-20 provides an overall summary of all chemical and biological lines of evidence, indicating the extent of chemical and biological impact to the WBOR watershed from Elizabeth Mine contaminant sources. Assessments of chemical and biological lines of evidence indicate that Site contaminants adversely affect the fish and benthic communities.

The biological community (benthic organisms and fish) is severely impacted in Copperas Brook, the upper reach of Lord Brook below the South Open Cut, and in the Mixing Zone of the WBOR below Copperas Brook. The WBOR does not achieve conditions similar to upstream (Reference) locations until some point below Union Village Dam, although algae metals concentrations remain high below the dam. Surface water and sediment collected from Copperas Brook, the first section (upstream) of the Mixing Zone, and the air vent are highly toxic to aquatic organisms, such that survival of aquatic receptors in this area is not likely. The toxicity test results indicate that these toxic effects (mortality of the biota from exposure to the water or sediments) are not present below the Mixing Zone. The benthic and fish surveys of the WBOR indicate that the Air Vent contribution to the WBOR contamination is not significant in terms of biological impact, even though water chemistry results indicate the potential for impacts to the aquatic organisms in this stretch of the river.

Collectively, the various lines of evidence suggest that EPA Location 27, situated upstream of the confluence of the WBOR with the EBOR, represents the best estimate for the location where the WBOR achieves Vermont Water Quality Criteria for biological metrics. Full recovery to upstream (Reference) conditions is not observed until Location 44 at Union Village Dam. Numerical VTWQS are exceeded as far downstream as EPA Location 44. The distance from the Copperas Brook confluence to EPA Location 44 is approximately six miles.

Since all of the lines of evidence show that Copperas Brook and the Mixing Zone are the most severely impacted, it can be inferred that TP-1, TP-2, and TP-3, which are the contaminant sources located within the Copperas Brook drainage, are the cause of the impacts to the WBOR. These impacts firmly support the need for an early cleanup action (NTCRA) to address the principal sources of AMD.

1.7.2 Streamlined Human Health Risk Assessment

The initial risk evaluation focused on whether the Site data strongly suggest the need for an immediate action to prevent exposure to contaminants found at the Site. A more detailed evaluation of the potential long-term threats at the Site will be the subject of the Baseline Human Health Risk Assessment that will be prepared as part of the RI/FS. Drinking water, residential soil, and residential dust sampling results do not suggest a short-term human health exposure above acceptable levels.

EPA has sampled nine residential wells in the immediate vicinity of the Site and one well located within a mile of the site. Several of the water supplies adjacent to the Site were sampled numerous times in 2000. One water supply well did not meet federal drinking water standards for two metals (copper and cadmium). The residents and landowner were promptly notified. The residents have since re-located and the well is no longer in use. All of the other water supply wells were found to meet federal and state primary drinking water standards. Table 1-4 presents the residential water supply data collected to date.

EPA collected residential soil, indoor dust, and air samples from three residences along Mine Road. The soil data revealed several instances where levels of iron, lead, and thallium warrant further study as part of the RI/FS, because the detected levels were higher than background concentrations. The concentrations of these metals were not at levels considered to represent an acute (short-term) hazard (see Table 1-11). Elevated lead levels were found in some of the residential dust samples. The source of the lead is not yet known. All of the water, soil, and dust data have been provided to the residents and the Vermont Department of Public Health. A more detailed evaluation of the soil and dust data will be presented in the Baseline Human Health Risk Assessment. EPA submitted the drinking water, soil, and dust data to the ATSDR. The health consultation from ATSDR confirmed EPA's assessment that the residential water and soil data do not indicate any current risks that would warrant immediate EPA action. Appendix H presents the ATSDR Health Consultation Reports. The Baseline Human Health Risk Assessment that will be developed as part of the RI/FS will more fully evaluate the current and future potential threats to human health and the environment, including an assessment of the effects of long-term exposure to windblown dust and the exposed tailings.

1.7.3 Selection of Preliminary Removal Goals

The preliminary risk assessment work completed to date identified clear ecological risks resulting from direct and indirect contact and exposure to contaminated surface water in the WBOR. The overall goal of the NTCRA is to control the release of the AMD from the Site to promote the restoration of the WBOR to VTWQS for freshwater rivers. Both biological and numeric measures will be used to evaluate the success of the NTCRA. Biological water quality standards (VTDEC, 2000) include eight measures of community structure for benthic invertebrates and fish in freshwater streams. Chemical water quality standards are chemical concentrations in surface water that, if achieved, will reduce or eliminate risks associated with exposure to Site-related contaminants and thus will allow river ecosystems to recover so that biological standards can be met.

The measures of effectiveness of this NTCRA will be the extent to which surface water quality in the WBOR below the confluence with Copperas Brook meets VTWQS for numerical and biological measures. The primary measure of success for this NTCRA will be the quality of the surface water within Copperas Brook and the section of the WBOR just below the confluence with Copperas Brook. Due to the presence of other sources of contamination above and below the confluence of Copperas Brook and the WBOR, the quality of Copperas Brook is the best measure of the actions taken to address the tailings. The other source areas and naturally occurring levels of certain metals and alkalinity within the WBOR will all be taken into account when evaluating the success of the NTCRA. Secondary goals include addressing community concerns relating to historic preservation and community impacts as well as increasing the stability of the tailings piles.

2.0 Identification of Removal Action Scope and Objectives

This section presents the statutory limitations on removal actions, identifies the conditions that justify the performance of a NTCRA at the Elizabeth Mine Site, presents the overall goals and objectives of the proposed NTCRA, and identifies potential federal and state requirements with which the selected removal action must comply. A proposed NTCRA schedule is also provided.

The general objectives of the Elizabeth Mine NTCRA include the following:

- Achieve VTWQS (chemical and biological) as well as other applicable standards in the WBOR by preventing or minimizing discharge of water with mine-related metals contamination to Copperas Brook and the WBOR.
- Minimize the erosion and transport of tailings or contaminated soil into the surface waters of Copperas Brook and the WBOR.
- Evaluate stability of waste piles (tailings, waste rock, and leach piles) and modify slope configurations (re-grading, covering or buttressing) as necessary to provide for an acceptable level of long-term stability.
- Consider measures to minimize and avoid an adverse effect on historic resources at the Site, as required by the National Historic Preservation Act.
- Comply with all applicable federal and state regulations.

In addition to protection of human health, Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota ("Ecological Risk Assessment and Risk Management Principles for Superfund Sites", OSWER Directive 9285.7-28P, October 1999).

2.1 Statutory Limits on Non-Time-Critical Removal Actions (NTCRA)

40 CFR Part 300.415(b)(5) and Section 104(c)(1) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) set limits of 12 months and $2 million for fund-financed removal actions. An exemption from the time and dollar limitations in the statutes can be granted in situations where EPA determines that the proposed removal action is appropriate and consistent with the anticipated long-term remedial action. Implementation of any of the alternatives in this EE/CA will result in costs exceeding the NTCRA $2 million and 12-month statutory limits. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

2.2 Conditions That Justify a Removal Action

Section 300.415(b)(2) of the NCP lists a number of factors for EPA to consider in determining whether Site conditions indicate performance of a NTCRA is appropriate, including the following:

i) Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances, pollutants, or contaminants;
ii) Actual or potential contamination of drinking water supplies or sensitive ecosystems;
iii) Hazardous substances, pollutants, or contaminants in drums, barrels, tanks, or other bulk storage containers, that may pose a threat of release;
iv) High concentrations of hazardous substances, pollutants, or contaminants in soils largely at or near the surface, that may migrate;
v) Weather conditions that may cause hazardous substances or pollutants or contaminants to migrate or be released;
vi) Threat of fire or explosion;
vii) The availability of other appropriate federal or state response mechanisms to respond to the release, and
viii) Other situations or factors that may pose threats to public health or welfare or the environment.

An evaluation of the conditions at the Elizabeth Mine Site indicates that several of these factors are applicable, as described below.

(i) Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances, pollutants, or contaminants. There is current actual exposure of animals to hazardous substances, pollutants, and contaminants such that the benthic organism and fish communities have been severely impacted. A five-mile stretch of the WBOR violates VTWQS for both numerical and biological water quality measures. The entire one-mile stretch of Copperas Brook and the one-mile stretch of the WBOR downstream of its confluence with Copperas Brook were found to be severely impacted by the Site conditions, based upon fish and benthic surveys. In addition, there is a potential exposure to hazardous substances, pollutants, or contaminants from ingestion of ground water by individuals within close proximity to TP-3. A water supply was recently removed from use, due to contamination above federal and state drinking water standards.

(ii) Actual or potential contamination of drinking water supplies or sensitive ecosystems. Prior to the termination of the use of one water supply well, there was actual contamination of a drinking water supply by the mine waste. The potential for future contamination of water supplies remains for any future wells installed in close proximity to the tailings. The aquatic ecosystems of Copperas Brook and the WBOR have been substantially impacted by the tailings. Surface water data documents actual

contamination of the entire one-mile length of Copperas Brook and an additional five miles of the WBOR, extending to below the Union Village Dam. Sediment data suggests that contamination extends to the confluence of the Connecticut River, which is another three miles downstream of the dam. Site-related contamination has clearly resulted in significant impairment to ecosystems in the mine area.

(iv) High concentrations of hazardous substances, pollutants, or contaminants in soils at or near the surface that may migrate. High concentrations of metals (including aluminum, cadmium, chromium, cobalt, copper, iron, manganese, and zinc) have been detected in tailings materials exposed at the surface in the Elizabeth Mine area. Currently, a large portion of TP-1 and TP-2 (five to seven acres) has little to no vegetated cover. TP-3 is largely unvegetated. Contamination is being continually released through erosion and acid mobilization of the metals. Local residents report that migration of dry oxidized tailings through wind-blown dust has been a problem in the past. It could continue to be a problem if actions are not taken to stabilize (cover) the TP-1 and TP-2 tailings.

(v) Weather conditions that may cause hazardous substances, pollutants or contaminants to migrate or be released. The principal contaminant transport pathway at the Elizabeth Mine Site is storm water runoff. The mine is situated in a mountain valley in east central Vermont, where storm conditions through much of the year produce short-term rainfall events. Annual precipitation averages approximately 35 inches in the South Strafford area. Erosion of exposed tailings results in acid drainage with high dissolved and suspended metals runoff, which flows into the headwaters of Copperas Brook and ultimately to the WBOR. Spring snowmelt conditions contribute the greatest metal and acid loads to the surface water environment over a four-week period from early April to early May. Snow pack at the beginning of the spring melt is typically in the three to four-foot range throughout the Copperas Brook watershed. Catastrophic failure of TP-1 resulting from extreme weather events or small earthquakes could have a significant long-term adverse effect the quality of the WBOR.

(vii) The availability of other appropriate federal or state response mechanisms to respond to the release. There are no other known federal or state funds or response mechanisms available to finance this action.

Combined, these factors indicate that the tailings, waste rock, and heap leach piles at the Elizabeth Mine Site constitute a threat to public health or the environment (principally to sensitive ecological receptors) through the release, or potential release, of hazardous substances, pollutants, and contaminants into the environment. A NTCRA is therefore appropriate to abate, prevent, minimize, stabilize, mitigate, or eliminate such threats. In particular, a NTCRA is necessary to provide source control measures to remove, control, or contain the risk to the sensitive ecological receptors within Copperas Brook and the WBOR as well as potential future users of the ground water.

This Removal Action is designated as non-time-critical, because more than six months planning time is available before on-site activities must be initiated. Prior to the actual performance of a NTCRA at this Site, Section 300.415(b)(4) of the NCP requires that an EE/CA be performed to evaluate response options.

2.3 Applicable or Relevant and Appropriate Requirements

Section 300.415(j) of the National Contingency Plan (NCP) requires that "Fund-financed removal actions under CERCLA Section 104 and removal actions pursuant to CERCLA Section 106, shall, to the extent practicable, considering the exigencies of the situation, attain Applicable or Relevant and Appropriate Requirements (ARARs) under federal environmental or state environmental or facility siting laws".

In determining whether compliance with ARARs is practical or practicable, EPA may consider appropriate factors, including the urgency of the situation and the scope of the removal action to be performed. An alternative that does not meet an ARAR under federal environmental or state environmental or facility siting laws may be selected under the following circumstances (40 CFR 300.430[f][1][ii][C]):

1. The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement;
2. Compliance with the requirement will result in greater risk to human health and the environment than other alternatives;
3. Compliance with the requirement is technically impracticable from an engineering perspective;
4. The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirements, or limitation through use of another method or approach;
5. With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply the promulgated requirement in similar circumstances at other remedial actions within the state; or
6. For fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the Site and the availability of Fund monies to respond to other sites that may present a threat to human health and the environment.

Inherent in the interpretation of ARARs is the assumption that protection of human health and the environment is ensured.

2.3.1 Terms and Definitions

The following are explanations of the terms and definitions used throughout this ARARs discussion:

Applicable requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site" *(52 FR32496*, August 27, 1987). An example of an applicable requirement is compliance with the NHPA for a site that has been determined eligible for listing in the National Register of Historic Places.

Relevant and appropriate requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site" *(52 FR 32496).* For example, while the federal maximum contaminant levels (MCLs) established under the Safe Drinking Water Act are applicable standards for public water supplies, MCLs are considered relevant and appropriate for use as groundwater cleanup levels when the groundwater is considered an actual or potential drinking water source.

Requirements under federal or state law may be either applicable or relevant and appropriate to CERCLA cleanup actions, but not both. Requirements must be both relevant and appropriate for compliance to be necessary. In the case where both a federal and a state ARAR are available, or where two potential ARARs address the same issue, the more stringent regulation must be selected. The final NCP states that a state standard must be legally enforceable and more stringent than a corresponding federal standard to be relevant and appropriate (*55 FR 8756*, March 8, 1990).

CERCLA on-site response actions must only comply with the substantive requirements of an ARAR and not the administrative requirements. “No Federal, State, or local permit shall be required for the portion of any removal or remedial action conducted entirely onsite, where such remedial action is selected and carried out in compliance with this section” [CERCLA § 121(e) (1)]. As noted in the ARARs guidance (EPA, 1988):

> *The CERCLA program has its own set of administrative procedures which assure proper implementation of CERCLA. The application of additional or conflicting administrative requirements could result in delay or confusion.*

Substantive requirements pertain directly to the actions or conditions at a site, while administrative requirements facilitate their implementation. The NCP defines on-site as "the area extent of contamination and all areas in very close proximity to the contamination necessary for implementation of the response action". EPA recognizes that certain administrative requirements, such as consultation with state agencies and reporting, are accomplished through the state involvement and public participation requirements of the NCP. Off-site response actions must comply with both the substantive and administrative requirements of an applicable (but not a relevant and appropriate) regulation.

In the absence of federal- or state-promulgated regulations, there are many criteria, advisories, and guidance values that are not legally binding, but that may serve as useful guidance for response actions. These are not potential ARARs, but are "to-be-considered" (TBC) guidance. These guidelines or advisory criteria should be identified if used to develop cleanup goals or if they provide important information needed to properly design or perform a response action. Three categories of TBC information are as follows:

(1) Health effects information with a high degree of certainty (e.g., reference doses),
(2) Technical information on how to perform or evaluate site investigations or response actions, and
(3) Regulatory policy or proposed regulations. For example, EPA Region III Residential Risk Based Concentrations and Region IX Preliminary Remediation Goals (Residential) provide guidance to be considered to assess the health implications during site activities.

ARARs are divided into the three categories listed below.

- **Location-specific ARARs** "set restrictions upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations" (*53 FR 51394*). In determining the use of location-specific ARARs for selected remedial actions at CERCLA sites, the jurisdictional prerequisites of each of the regulations must be investigated. In addition, basic definitions and exemptions must be analyzed on a site-specific basis to confirm the correct application of the requirements. For example, federal and state regulations concerning wetlands apply at a site where remedial activities may impact an existing wetland.
- **Chemical-specific ARARs** are usually health- or risk-based standards that limit the concentration of a chemical found in or discharged to the environment. They govern the extent of site remediation by providing either actual cleanup levels, or the basis for calculating such levels. Chemical-specific ARARs may also be used to indicate acceptable levels of discharge in determining treatment and disposal requirements, and to assess the effectiveness of future remedial alternatives. For example, state water quality standards would apply as cleanup standards at a site where contaminated surface water is the subject of a cleanup.
- **Action-specific ARARs** set controls or restrictions on particular kinds of activities related to the management of hazardous waste (*53 FR 51437*). Selection of a particular response action at a site will invoke the appropriate action-specific ARARs that may specify particular performance standards or technologies, as well as specific environmental levels for discharged or residual chemicals. For example,

the federal and state air standards apply under many circumstances where a treatment technology involves air emissions.

The Occupational Safety and Health Administration (OSHA) has promulgated standards for protection of workers who may be exposed to hazardous substances at Resource Conservation and Recovery Act (RCRA) or CERCLA sites (29 CFR Part 1910.120 and 1926.65). EPA requires compliance with the OSHA standards in the NCP (40 CFR 300.150), not through the ARAR process. Therefore, the OSHA standards are not considered ARARs. Although the requirements, standards, and regulations of OSHA are not ARARs, they will be complied with during response activities.

Identification and evaluation of ARARs is an iterative process, which continues throughout the response process as a better understanding is gained of site conditions, contaminants, and response alternatives. Therefore, preliminary lists of ARARs and their relevance may change through time as more information is obtained and as the preferred alternative is chosen.

2.3.2 Location-Specific ARARs

Location-specific ARARs are related to the presence of specific natural or manmade features or potentially affected resources at the Site. ARARs relating to wetlands, floodplains, wildlife, archaeological, and historical resources have been identified. Table 2-1 contains a list of the location-specific ARARs that may apply to the removal alternative evaluated in this EE/CA. The ARARs for each cleanup alternative are discussed in Section 4.

The text below includes a discussion of several key location specific ARARs that apply to the NTCRA. EPA is seeking comment from the public regarding the following:

(1) Impacts to wetlands and floodplains
(2) Adverse effects to historic properties

Floodplain Impacts: The Floodplain Management (Executive Order 11988, 40 CFR 6.302(b) and 40 CFR 6, App. A (Policy on Implementing E.O. 11988) and Vermont Watershed Protection and Flood Prevention, Title 10, V.S.A. Chapter 39 establish guidelines for any federal activities that may impact floodplains. Some of the construction activities anticipated under the NTCRA will be performed within the floodplain areas of the upper portion of the Copperas Brook watershed. The activities described in the EE/CA are not expected to impact floodplain areas of the WBOR. The cleanup alternative must be design to ensure no net loss of floodplain storage (with respect to surface water drainage from snowmelt or precipitation). If necessary, temporary storage/holding areas may need to be constructed in the Copperas Brook watershed for excess storm water runoff to prevent flooding.

Wetland Impacts: The Protection of Wetlands (Executive Order 11990), 40 CFR 6.302(a) and 40 CFR 6, App. A (Policy on Implementing E.O. 11990) requires federal agencies to avoid undertaking or providing assistance for new construction located in wetlands unless there is no practicable alternative and the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use. Section 404 of the Clean Water Act, (33 U.S.C. 1251 et seq), and 40 CFR 230 and 33 CFR 320-330) require that any alternative selected result in the least damaging practicable alternative to wetland resources. At the Elizabeth Mine Site the wetlands present are severely degraded and will be displaced as part of the construction of the remedy. Mitigation measures will be implemented to address the loss of wetland resources on the Site.

Vermont Water Resources Management, Title 10, V.S.A. Chapter 37, establishes guidelines for the protection of water, ground water, and wetland resources. EPA must evaluate potential effects of any new construction in wetlands and identify, evaluate, and as appropriate, implement alternative actions that may avoid or mitigate adverse impacts to wetlands and other water bodies. Vermont Wetlands Rules (Vermont Agency of Natural Resources, Water Resources Board, 12-004-056) establishes criteria for delineating Class One and Class Two wetlands, which are considered significant wetlands, and sets forth allowed and conditional uses for these wetlands. The uses must not have undue adverse impacts on the significant functions of the wetland. Vermont's Land Use and Development Law (Act 250), Title 10 V.S.A. Chapter 151 (Criterion 1(G) also requires protection of wetland resources located within a Site.

The State of Vermont has identified portions of the surface of TP-1 as a designated Class 2 Wetland (Quackenbush, August 2001, personal communication). This area is the receiving point for contaminated surface water flow from upper Copperas Brook. Typical wetland vegetation (cattails and phragmites) occupies an area measuring less than one acre to the south of the "permanent" pond on the east-side of TP-1. A small stand of cattails (measuring 30'x 75') has been established (naturally) at the toe of TP-1 in an area receiving seep water from the base of the tailings. A small stand of cattails is also present at the mouth of the main mine adit, used most recently during the WWII-era mining campaign. Each alternative considered in this EE/CA will have a significant negative impact on the wetlands on the surface of and immediately below TP-1. These two wetland areas (less than one acre in total area) must be completely eliminated to achieve the goals of each alternative. The extent of the mitigation for impacting wetlands will be determined during design. The wetlands to be constructed as part of the passive treatment systems cannot be considered mitigation, but will host similar vegetation and provide more quality habitat and ecological diversity than the wetlands that will be destroyed by the NTCRA project. The combination of holding ponds and other passive treatment system components will provide open water habitat that will complement the wetland ecosystems. Once constructed, the treatment system wetlands must be preserved and reconstituted (mitigated with replanting) following periodic cleanout.

Impacts to Historic Mine Features: Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470f), requires EPA to take into account the effect of all of its actions on historic properties. For purposes of EPA compliance with the NHPA, the term "historic property" will be applied to the Elizabeth Mine as defined in 36 CFR § 800.16(l)(1), "*Historic property means any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register of Historic Places …*" In order to be considered eligible, the site must meet at least one of four Criteria for Evaluation, 36 CFR §60.6, and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, the EPA has determined the Elizabeth Mine Site eligible for the National Register.

The EPA has determined the Site's significance to be best reflected by Criterion A: *Those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *Those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Throughout its history, the Elizabeth Mine has made significant contributions at the local, state, and national levels in the areas of commerce, economics, engineering, industry, and invention. The Elizabeth Mine was the site of a major U.S. copperas manufacturing plant that dominated production of this important industrial chemical during the mid-nineteenth century. It was the scene of several important firsts in American copper metallurgy, including successful mine-side smelting, large-scale smelting of sulfide ores, and smelting with hot blast and anthracite, and successful use of chromite refractories. After its World War II revival, it became one of the 20 most productive copper mines in the U.S. and was the largest and most productive copper mine in New England.

The Elizabeth Mine landscape has the potential to yield information on industrial activities spanning almost 160 years. Standing structures, mine-related features, and archaeological sites pertain to various phases of copper and copperas extraction, including ore processing, beneficiation and smelting activities, transportation, and worker accommodation. In keeping with Criteria D, such information could contribute significantly to knowledge about industrial processes, mining lifestyles, and the dynamics of mining systems.

The integrity of the location, setting, feelings and association of the Elizabeth Mine help to define what makes the historic property important to the local communities. The mining landscape is complex with multiple overlapping layers. There remains visible landscape evidence of the nineteenth-century copperas production and mid-twentieth century copper production in the forms of waste rock, roast beds, heap leach piles, and flotation tailings. Tailings and waste rock piles are the most obvious, massive, and powerful evidence of the significant contributions to copper mining history that the Elizabeth Mine has had throughout its history. Tailing Piles 1, 2, and 3 that are most readily identified as the contributing and defining features of the historic property.

Other important features include standing structures, the open mine cuts, Furnace Flat, stone foundations, brick and clustered remnants of cut timber, and associated mine artifacts.

EPA has been working with the SHPO and local communities to fully define the historic properties and potential construction-related impacts. From these meetings with a diverse group of interested parties, the EPA has identified historic features of the site that are valued by the surrounding communities. These include the copperas works of TP-3, features related to the Tyson-era of mining and smelting, all of the remaining standing structures, Furnace Flat, the North and South Mine Cuts, and mining landscape itself.

Construction activities and associated actions considered in this EE/CA will have an affect on features of the historic property at the Elizabeth Mine Site. The Area of Potential Effects (APE) means, "…the geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties…" 36 CFR §800.16(d). The preliminary APE for direct effects is shown in Figures 3-2 through 3-6. The APE will be further defined to address indirect effects, cumulative effects, and other effects when the remediation option is selected and the construction design is completed.

State historic protection standards under Vermont's Land Use and Development Law (Act 250), Title 10 V.S.A. Chapter 151 (criterion 8) will also be addressed a part of this removal action.

EPA will work with the SHPO and other consulting parties to develop a Memorandum of Agreement (MOA) between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

Vermont Land Use and Development Law; Title 10, Chapter 151 of Vermont Statutes Annotated (Act 250): CERCLA response actions are exempted from obtaining Act 250 permits, but must meet the substantive requirements of
Act 250. The following location-specific criterion will be addressed in implementing the removal action:

- Impact on wetlands (criterion 1[G])
- Impact on historic sites (criterion 8)

The response action contractor will be responsible for ensuring that any off-site material source areas located in Vermont comply with Act 250

2.3.3 Chemical-Specific ARARs

Table 2-2 contains a summary of the chemical-specific ARARs for the removal alternatives evaluated in this EE/CA. The ARARs for each alternative for the Site are identified and discussed in greater detail in Section 4.

2.3.4 Action-Specific ARARs

Table 2-3 contains a summary of the action-specific ARARs for the removal alternatives evaluated in this EE/CA. The ARARs for each alternative for the Site are identified and discussed in greater detail in Section 4. Key action-specific ARARs are described below.

Vermont Land Use and Development Law; Title 10, Chapter 151 of Vermont Statutes Annotated (Act 250): CERCLA response actions are exempted from obtaining Act 250 permits, but must meet the substantive requirements of Act 250. The following action-specific criterion will be addressed in implementing the removal action:

- Erosion control (criterion 4), and
- No undue water or air pollution (Criterion 1)
- Maintain natural condition of stream whenever feasible (Criterion 1(E)and
- Construction-related dust (criteria 1 and 8)

The response action contractor will be responsible for ensuring that any off-site material source areas located in Vermont comply with Act 250.

Resource Conservation and Recovery Act (RCRA) Subtitle C Hazardous Wastes: The tailings and solid wastes present at the Site are not “hazardous waste” as defined by RCRA 40 C.F.R. 261. Under 40CFR 261.4(b)(7) (Bevill Exclusion), solid wastes from the extraction, beneficiation, and processing of ores and minerals (including coal) are excluded from the definition of hazardous waste, and therefore not subject to RCRA Subtitle C requirements. These wastes are excluded because implementation of Subtitle C requirements would be unnecessary, technically infeasible, or economically impracticable, due to the types of waste and conditions commonly found at mining sites. These conditions commonly include high volumes of waste with low toxicity and highly mobile constituents and large areas of contamination.

EPA has performed Toxic Compound Leach Procedure (TCLP) analyses of the tailings to determine if the tailings would be considered hazardous. Results indicate that the tailings do not exceed the numerical criteria that would result in the tailings being considered “hazardous waste”. As a result, the RCRA 40 C.F.R. 264 and 265 closure and post-closure standards are not ARARs.

Vermont Solid Waste Management Rules: EPA has also evaluated whether the tailings are subject to the requirements that apply to ‘solid waste”. The Vermont Solid Waste Management Rules (10 VSA Chapter 159) (VTSWMR) provide an exemption for earth materials resulting from mining, extraction, or processing operations except where there is a determination that these materials may pose a threat to public health and safety, the environment, or cause a nuisance. Due to the ecological risks that these materials pose to downstream aquatic resources, EPA has determined that the tailings are "solid waste" for purposes of implementing the removal action at the Site.

Under CERCLA, EPA has the authority to make determinations on how State ARARs will be implemented regarding a CERCLA response action. In reviewing the alternatives for addressing the risks posed by this Site, EPA has determined that specific sections of the VTSWMRs are applicable to the cleanup actions at the Elizabeth Mine Site. The siting requirements of the VTSWMR would only apply if the cleanup required an expansion of the solid waste footprint. This is unlikely, therefore, the siting requirements are not likely to apply. The VTSWMR stipulate design specifications for aspects of cap/cover construction and performance including cover material, cover design, and grading requirements.

The major requirements that apply to this action are:

(1) A final cover composed of 18 inches of material with a permeability less than $1x10^{-5}$ cm/sec and six inches of top soil. Alternative cover designs (substituting a geomembrane for the soil layer) may be approved; and
(2) A final surface grade no less steep than five percent and no more steep than 33%.

EPA has determined that certain requirements of the VTSWMR would conflict with the federal and state historic preservation requirements for the tailings, waste rock, and heap leach piles. The visual appearance (color, shape, and size) are critical elements of the historic significance of the tailings, waste rock, and heap leach piles. In addition, the local community has expressed a strong interest in alternatives that would reduce truck volume on the local roads. 10 V.S.A. Chapter 159, Section 6613 contains provisions for invoking, if necessary, a variance from the VTSWMR subject to certain conditions. These conditions are:

(1) The variance proposed does not endanger or tend to endanger human health or safety. None of the alternative measures considered in the EE/CA would endanger or tend to endanger human health or safety;
(2) Compliance with the rules from which variance is sought would produce serious hardship without equal or greater benefits to the public. The specific requirements of the VTSWMR would produce a serious hardship to the preservation of the historic resources at the Site without equal or greater benefit given that the alternative measures proposed for TP-1 and TP-2 would accomplish an equivalent level of protection with respect to human health and the environment, for less cost, and with less impact to the historic resources. The alternative measures for TP-3 would also achieve greater preservation of historic

resources with equivalent protection of public health and the environment subject to the State of VT accepting the long-term maintenance costs;

(3) The variance granted does not enable the applicant to generate, transport, treat, store, or dispose of hazardous waste in a manner which is less stringent than that required by the provisions of Subtitle C of the Resource Conservation and Recovery Act of 1976, and amendments thereto, codified in 42 U.S.C. Chapter 82, subchapter 3, and regulations promulgated under such subtitle. This provision is satisfied since at the Elizabeth Mine no hazardous waste is present.

In determining whether a variance to the VTSWMR is warranted for the proposed removal action, EPA considered, as required by the 10 V.S.A. Chapter 159, Section 6613:

(a) Whether the relative interests of other owners of property likely to be affected and the general public were considered. The alternatives considered address concerns expressed by local property owners and the general public regarding the protection of historic resources and reducing truck traffic and other disruptions to the community.

(b) Whether the variance could be implemented within the following limitations:

(1) That there is no practicable means known or available for the adequate prevention, abatement or control of the air and water pollution involved. When the adequate prevention, abatement or control of the air and water pollution is evaluated in light of the federal and state requirements regarding historic preservation and community concerns regarding truck traffic and historic preservation, there were no other alternatives available that would address these concerns, address the risks posed to aquatic resources at the Site, and comply with the remaining criteria of the VTSWMR. If at a later date a means for prevention, abatement or control become known and available, EPA will consider modifying the removal action to comply with the relevant requirements of the VTSWMR subject to the variance.

(2) The variance shall be for a period not to exceed such reasonable time as is requisite for the taking of the necessary measures. The variance shall contain a time schedule for the taking of action in an expeditious manner and shall be conditioned on adherence to the time schedule. The variance required under the alternatives for this removal action would be in effect permanently or until such time as alternatives exist for addressing the risks posed at the Site while preserving the Site’s historic resources.

In addition, the VTANR has recently proposed a revision to the VTSWMR that would create a waiver provision within the regulations. If the proposed regulation is promulgated prior to EPA signing the Action Memorandum for implementing the removal action, EPA will consider whether it will invoke either a waiver or variance of the regulation in order to address the use of alternative measures instead of the criteria listed in the VTSWMR.

Surface Mining Control and Reclamation Act: The Surface Mining Control and Reclamation Act of 1977 (SMRCA) governs activities associated with coal exploration and mining. Because the standards promulgated under SMRCA are intended for active coal mines, they will not be applicable to actions at Superfund mining sites. However, the standards found in 30 CFR Parts 816 and 817, which govern surface mining activities and underground mining activities, respectively, may be relevant and appropriate at inactive CERCLA mining sites where activities similar to SMCRA-regulated activities occur. This is because SMCRA regulations often address circumstances that are similar and establish performance objectives that are consistent with the objectives of a CERCLA investigation.

Clean Water Act: The discharge from the passive treatment systems will be required to meet federal Clean Water Act requirements under the National Pollution Discharge Elimination System (NPDES) or the VTWQS. Each passive treatment system will be designed to discharge water in compliance with the Clean Water Act and VTWQS. The point of compliance for the discharge will be determined during the design.

2.4 Non-Time Critical Removal Action Schedule

The schedule in Figure 2-1 shows key administrative steps in the NTCRA process. The NCP requires a public comment period of 30 days following submittal of the Final EE/CA. An additional 30 days are given for EPA to respond to significant comments received during the public comment period. The Action Memorandum is generally signed within 60 days following the response to comments. The schedule for completion of the removal actions is dependent upon approved funding.

Unless a financially viable responsible party can be located, it is likely that EPA will be required to implement and pay for the NTCRA, excluding Post-Removal Site Control (PRSC). PRSC will be paid by the State of Vermont. If full funding for the NTCRA is not available to EPA, a *phased funding strategy* will be implemented. The individual components of any of the alternatives considered in this EE/CA may be implemented in two or more phases, as determined to be appropriate during design and as required by the availability of funding.

3.0 Development of Removal Action Alternatives

3.1 Overview

The guidance for completion of Non-Time-Critical Removal Actions (NTCRA) requires that the goals and objectives of the NTCRA are consistent with and supportive of the Remedial Program goals and objectives. EPA is committed through the CERCLA process to addressing all known and/or suspected sources of contamination at the Elizabeth Mine Site through either the NTCRA or Remedial programs. The NTCRA addresses contamination associated with TP-1, TP-2, and TP-3. Source areas that will be addressed in the Remedial Program include the air vent, the South Open Cut and South Mine, and the underground flooded mine workings (mine pool).

3.2 Statutory and Policy Considerations

Relevant statutes and policies were identified and reviewed to help formulate the range of removal alternatives. These are summarized in the following subsections.

3.2.1 Statutory Considerations

General response actions describe categories of removal actions that may be used to satisfy removal action objectives by eliminating, reducing, or controlling risks and provide a basis for identifying specific removal technologies. Potentially applicable general response actions for a source control NTCRA include implementing administrative measures to prevent, reduce, or control exposure; removing contaminants to prevent, reduce, or control exposure or prevent a release; and, providing treatment to reduce the toxicity, mobility, or volume of contaminants.

The NCP (40 CFR 300.415 (e)) identifies appropriate removal actions that address risks to the public health or welfare, or the environment including, but not limited to, the following:

1. Fences, warning signs, or other security or site control precautions - where humans or animals have access to the release
2. Drainage controls, (e.g., run-off or run-on diversion), where needed, to reduce migration of hazardous substances or pollutants or contaminants off-site or to prevent precipitation or run-off from other sources (e.g., flooding), from entering the release area from other areas
3. Stabilization of berms, dikes, or impoundments or drainage/closing of lagoons, where needed, to maintain the integrity of the structures
4. Capping of contaminated soils or sludges, where needed, to reduce migration of hazardous substances or pollutants or contaminants into soil, ground, or surface water, or air

5. Using chemicals and other materials to retard the spread of the release or to mitigate its effects, where the use of such chemicals will reduce the spread of the release
6. Excavation, consolidation, or removal of highly contaminated soils from drainage or other areas, where such actions will reduce the spread of or direct contact with the contamination
7. Removal of drums, barrels, tanks, or other bulk containers that contain or may contain hazardous substances or pollutants or contaminants, where it will reduce the likelihood of spillage, leakage, exposure to humans, animals, or the food chain; or fire or explosion
8. Containment, treatment, disposal, or incineration of hazardous materials, where needed, to reduce the likelihood of human, animal, or food chain exposure
9. Provision of alternative water supply, where necessary, to immediately reduce exposure to contaminated household water, and continuing the supply until such time as local authorities can satisfy the need for a permanent remedy

CERCLA §9604(a)(2) and the NCP (40 CFR 300.415(c)) provide that removal actions shall, to the extent practicable, contribute to the efficient performance of any anticipated long-term remedial action with respect to the release of concern. In addition, Section 121(b) of CERCLA expresses the preference for treatment over conventional containment or land disposal to address a principal threat at a site. This preference for treatment applies explicitly to remedial actions, but the overall strategy is also appropriate for removal actions.

3.2.2 Policy and Guidance Considerations

The principal guidance used for development of this EE/CA was the EPA guidance for NTCRAs: "Guidance for Conducting Non-Time-Critical Removal Actions Under CERCLA" (EPA, 1993). The guidance document provides information and procedures/activities for performing NTCRAs. In addition, EPA’s policy statement “Ecological Risk Assessment and Risk Management Principles for Superfund Sites”, OSWER Directive 9285.7-28P, October 1999, was considered in support of developing a NTCRA for a Site with risks that are primarily attributable to ecological receptors. In that policy statement EPA confirms that in addition to protection of human health, Superfund’s goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota.

3.3 Assessment of General Response Actions and Response Technologies

To meet the Removal Action Objectives and ARARs, an evaluation of General Response Actions and Response Technologies was performed. Complete removal and off-site disposal of contaminants (to prevent, reduce or control exposure or mitigate/prevent a release) is not a practicable solution for the main tailings piles (TP-1 and TP-2). Together, these tailings piles represent approximately two million cubic yards of material. However, removal of all, or a portion of TP-3, with subsequent incorporation into TP-1, has been considered as a viable approach to address ongoing contaminant releases from that portion of the Site. Based upon the request of State of Vermont, the baseline assumption for this EE/CA is that at least some portion of TP-3 (ranging from 20% to 100%) will remain in place as part of the historic preservation activities at the Site. Therefore, measures to capture and treat contaminated water resulting from storm water runoff and ground water seeps from this area are included in each cleanup option. Each Alternative includes passive treatment systems to address the contaminated runoff from TP-3 and the seeps along the toe of TP-1 and TP-2. Covering or capping the waste materials in TP-1 and TP-2 represents the most practical and cost-effective response measure to reduce the mobility of contaminants by eliminating, or greatly reducing, the generation of AMD. However, covering or capping does not address the toxicity of the contaminants, nor does it reduce the volume of the contamination source material.

3.3.1 Overview and Summary of Alternatives

Section 300.415(e) of the NCP provides examples of removal actions appropriate for a range of situations, but sets forth no specific requirements for identifying and evaluating removal alternatives. EPA guidance on preparing an EE/CA recommends identifying and assessing a limited number of alternatives appropriate for addressing the removal action objectives, while considering the CERCLA preference for treatment. The guidance also suggests the use of “presumptive remedies” (such as capping) to limit the wide spectrum of potential alternatives for the NTCRA.

The development of Removal Action Alternatives for the Elizabeth Mine involved an initial screening step that was summarized in the Alternatives Analysis Report (ADL April 2001). That report described the evaluation of a wide array of technologies available to mitigate and/or control the production of AMD. Many of these approaches are well established with proven track records of success. Others are emerging technologies without a long track record. This EE/CA includes a thorough evaluation of those alternatives recommended for further consideration after review of the Alternatives Analysis Report (AAR) and the draft EE/CA by the State of Vermont, the EMCAG, and its technical advisors. A brief summary of the AAR follows.

Technologies for addressing AMD can be categorized under the following general approaches:

Treatment Technologies. These technologies treat AMD after formation through biological or chemical reactions which reduce acidity and/or metals concentrations in AMD-contaminated waters.

Containment Technologies. These technologies prevent or reduce the formation of AMD by isolating the AMD generating wastes from oxygen and/or water infiltration, or by using chemical and biological methods that prevent or retard the formation of AMD.

***Combined Containment and Treatment*.** These technologies both limit AMD formation and treat any residual contamination that exists after control mechanisms are in place. Response approaches for mine sites often incorporate both containment and treatment techniques in order to achieve water quality and land use objectives.

Table 3-1 presents a summary of potential response technologies considered in the initial screening contained in the AAR.

Table 3-1: Technologies Considered in the Initial Screening Document (AAR)

Technology Reviewed		Retained for Preliminary Evaluation	April 2001 Alternative That Contained These Components
Control			
Caps	Multi-barrier	Yes	2A, 2B, 2C
	Soil Cover	Yes	3
	Organic Waste Cover	No	——
	Chemical Hardpan Cap	Yes	3
Groundwater Control		Yes	1, 2, 3, 4
Inundation/Wet Covers		Yes	4
Slurry Walls and Grout Curtains		No	——
SurfaceWater Diversion Channels		Yes	1, 2, 3, 4
Treatment			
Active Treatment Plant		Yes	1
Biocides		No	——
Buffering Systems		Yes	2, 3, 4
Contructed Wetlands	Aerobic Wetlands	Yes	2, 3, 4
	Anaerobic Wetlands	Yes	2, 3, 4
Limestone Drains/Channels		Yes	2, 3, 4
Limestone Ponds		Yes	2, 3, 4
Settling Ponds	SAPS	Yes	2, 3, 4
	Oxidation	Yes	2, 3, 4
Vertical Flow Systems		No	——
Reaction Walls		No	——
Sulfate Reducing Bacteria (SRB)		Yes	2, 3, 4

A single remedial technology seldom proves sufficient for addressing the complex and multi-faceted environmental issues at former mining and milling sites. Four response scenarios (alternatives) were developed and presented in the AAR, representing the technologies that hold the most promise for success.

Each alternative from the AAR is briefly described in Table 3-2.

Table 3-2: Response Alternatives Developed and Evaluated in AAR (April 2001)

Alt. #	Description	Technology Components	EE/CA Status
1	Collect and treat surface runoff with active treatment	• Surface water diversion • Runoff retention pond(s) • Chemical treatment plant • Sludge management systems • Erosion control and stabilization of tailings using a retention structure, most likely Roller Compacted Concrete (RCC)	Alternative not retained for analysis in EE/CA. Community and State were opposed to large long-term costs associated with total capture and treatment of the run-off.
2A	Hydraulic Containment	• Surface water diversion • "Passive" treatment of seeps at base of TP-1 • Excavate and move TP-2 and TP-3 onto surface of TP-1 • Regrade TP-1 to eliminate steep slope • Hydraulic isolation of combined tailings pile	Alternative not retained for analysis in EE/CA. Community and NHPA concerns eliminated this option.
2B	Hydraulic Containment: 2A, but leave portion of TP-3 in place	• Surface water diversion • "Passive" treatment of seeps at base of TP-1 and TP-3 • Excavate and move TP-2 and a portion TP-3 onto TP-1 • Regrade TP-1 to eliminate steep slopes • Hydraulic isolation of combined tailings pile	Alternative evaluated in EE/CA.
2C	Hydraulic Containment: 2B, but retain current surface profile of TP-1 and TP-2	• Surface water diversion • "Passive" treatment of seeps at base of TP-1 and TP-3 • Excavate and move (portion of) TP-3 onto TP-1 and TP-2 surfaces • Retain profiles of TP-1 and TP-2 with minimal regrading necessary to ensure positive surface drainage • Construct retention structures (e.g. RCC) to stabilize slopes • Hydraulic isolation of combined tailings piles (TP-1 and 2)	Alternative evaluated in EE/CA with some modifications regarding TP-3.
3	Soil cover	• Surface water diversion • "Passive" treatment of seeps at base of TP-1 and TP-3 • Regrade all three tailing piles (possibly retain portion of TP3) • Soil layer underlain by crushed limestone • Vegetate surface	Alternative evaluated in EE/CA. Alternative was evaluated as three separate soil cover approaches in EE/CA.
4	Wet Cover	• Surface water diversion onto surface of TP-1 and TP-2 • Re-grading of TP-1 and TP-2 to achieve terrace profile • Construct fens/wetlands on surface of TP-1 and TP-2 • Construct toe drain at base of TP-1 • Passive treatment of seeps at base of TP-1 • (possibly include passive treatment of portion of TP-3) • Soil cover over TP-1 and TP-2 • Re-vegetate soil cover and fens/wetlands	Alternative not retained for analysis in EE/CA. EPA and state eliminated this alternative due to technical concerns regarding this approach.

The results of the AAR evaluation and subsequent comments are summarized below:

- Alternatives 1 and 4 from the AAR were eliminated from further consideration in the EE/CA due to cost and technical considerations**.**
- Alternative 2A was eliminated from further consideration due largely to the proposed impacts to features of historic significance (complete excavation of TP-2 and TP-3).
- Alternatives 2B and 2C were retained for evaluation in the EE/CA.
- Alternative 3A was eliminated due largely to the impact to historic features.

Based on the results of the AAR and the subsequent comments from the public and state, EPA developed a focused list of five alternatives for consideration in the EE/CA. Alternatives 3B, 3C, and 3D evolved from further consideration of the original Alternative 3(A). Alternatives 3B, 3C, and 3D are evaluated in this EE/CA along with Alternatives 2B and 2C.

3.3.2 Common Elements/Technologies in Each Alternative

A number of treatment technologies are common to each alternative under consideration. This section provides a description of these technologies to minimize redundancy in the detailed description of alternatives. The common elements consist of the following:

- Passive treament systems for runoff/seeps
- Slope stabilization measures
- Covers/caps
- Approach for TP-3

3.3.2.1 Passive Treatment Systems

Preliminary design concepts for addressing mine wastes at the Elizabeth Mine incorporate “passive” treatment approaches into the long-term remedy to provide a low-cost sustainable solution to AMD when compared to a traditional waste water treatment plant. Passive treatment involves natural physical, biochemical and geo-chemical reactions and processes within a series of engineered treatment facilities with no mechanical systems with power demands (that typically require less maintenance than the active [treatment plant systems] once constructed and operational) to achieve treatment goals.

All cleanup options under consideration by EPA, and evaluated in this EE/CA, seek to minimize the infiltration of surface water into tailings and other waste materials through the diversion of surface water around the tailings. Several alternatives further seek to limit infiltration into the tailings in TP-1 and TP-2 through construction of caps or covers that limit infiltration. Infiltration rates vary depending on the surface cover/cap construction approach. Ultimately, all water that infiltrates into the tailings of TP-1 and TP-2 must be treated by passive systems at the toe of TP-1. Similarly, all runoff and seep water from acid generating waste materials within TP-3 must also be treated by passive systems, since the current approach involves retaining portions of TP-3.

Passive water treatment systems involve a variety of chemical and biochemical reactions, including (but not limited to) calcium carbonate dissolution, sulfate reduction, bicarbonate alkalinity generation, metals oxidation, and metals precipitation. Plant species in constructed wetlands may further stabilize mobile metals through uptake and incorporation into plant tissue.

The passive treatment systems proposed at Elizabeth Mine are designed for contaminated water to flow naturally from one component to another by gravitational forces. This eliminates the need for mechanical pumps to move water. The passive systems will be designed to achieve VTWQS in the receiving water (Copperas Brook). As the standards must be adjusted for hardness in the effluent and receiving water, the final treatment goals for the discharge from the passive treatment systems will be determined during the design.

The final configuration of specific passive treatment system components will be specified during the design process. The objectives of the passive system design phase will be to:

- Use design criteria and approaches that are proven (through other projects and Site-specific pilot studies) to be effective in treating the contaminants at the Site.
- Include modular components to accommodate adjustments to the treatment train over time.
- Balance the flows and contaminant concentrations to attenuate peak flows and loading and maintain minimal flow during dry periods.
- Allow for the most cost effective maintenance and replacement approach.
- Meet the discharge criteria that will be established pursuant to VTWQS and the Clean Water Act.

On the basis of available information collected from various locations around the site, EPA envisions two separate passive treatment systems: one for the treatment of TP-1 /TP-2 and one for the treatment of TP-3. The unique chemistry of seep and runoff water from these various areas dictates the need for separate passive treatment approaches. The following is a summary of the likely passive treatment elements and sequence for each runoff area:

TP-1/TP-2
- Anoxic Limestone Drain
- Holding Pond

- Successive Alkalinity Producing System (2 in parallel)
- Aerobic Wetland

TP-3
- Holding Pond
- Semi-Passive Alkalinity Doser (SPAD)
- Open Mixing Channel
- Settling Pond
- Sulfate Reducing Bacteria bioreactors (SRB)
- Aerobic Wetland

Bench and pilot scale testing is required to support the detailed design effort.

The following is a description of the various passive treatment system elements listed above for long-term AMD remediation at the Elizabeth Mine. Construction and Post Removal Site Control (PRSC) costs presented in this report are based on the assumptions and design elements provided.

Holding Pond

Stormwater, snowmelt, and ground water discharge from the foot of TP-1/TP-2 and TP-3 will be contained within holding ponds. The planned treatment system requires holding ponds at the toe of TP-1 and below TP-3 at the headwaters of Copperas Brook. Each holding pond will be designed "conservatively" to accommodate a 100-year storm event.

Holding ponds provide hydraulic retention of contaminated water prior to discharging to the main components of the passive treatment system. Hydraulic retention stabilizes flow rates to the treatment systems so that acid-shocks to bacteria do not occur. Holding ponds can also be useful in maintaining a minimal flow during periods of low precipitation. A secondary purpose of the holding pond is to allow settling of particulate matter prior to discharge to the treatment systems. Therefore, the pond will be constructed with an integrated sedimentation basin for capture and easy removal of coarse solids from erosion (especially for TP-3).

For TP-1/TP-2, the flow rate for the conceptual design is based on groundwater contributions, hydrologic buffering capacity, hydraulic storage depletion, and a contingency factor. For TP-3, two flow rates have been assumed in our conceptual design: 40 gpm if TP-3 remains intact (Option 1); and 20 gpm if Options 2 or 3 are considered. On both ponds, flow can be regulated at the holding pond discharge point to accommodate the full design capacity or reduced to retain water during dry periods, thus maintaining biological system saturation in subsequent treatment stages.

The holding ponds will be of earthen construction and will be designed to allow practical access for the periodic removal of sediments. The holding pond may be lined with clay or a geomembrane. The actual dimensions of the ponds will be determined during design. A pond depth of six feet deep was assumed in the EE/CA. A perimeter fence may be constructed around the ponds. The earthen structure will be constructed in a manner that conforms to the local topography to the greatest extent possible, both to minimize construction costs and improve the visual appearance.

Sizing Considerations for TP-1/TP-2

The holding pond at the toe of TP-1 will receive water captured in a toe drain at the bottom of the TP-1 north slope. Discharges from TP-2 seeps and the 1940s/50s adit may also be conveyed to the holding pond via the toe drain system. Discharge from the holding pond will be at the same rate as inflow into the passive treatment systems. The assumptions used to size the TP-1/TP-2 holding pond are discussed below.

- *Ground Water Contributions*: The “clean” stormwater diversion channel, which is proposed around the perimeter of TP-1 and TP-2, will be “keyed” into the underlying till layer and will intercept shallow ground water flowing from upgradient locations around the tailings piles. These perimeter drains will likely have a substantial impact on the amount of water passing through the tailings over time by removing the run-on and lateral contribution components to the overall hydrologic conceptual model. Future contribution of ground water to the total effluent toe-drain discharge is expected to be small, due to the low permeability of the glacial till which underlies the tailing piles. The EE/CA assumed a nominal future ground water contribution of 5-10 gpm.

- *Hydrologic Buffering Capacity*: The impact of storm events on the discharge rate of contaminated water from the toe of TP-1/TP-2 will be buffered by infiltration through the tailing piles; short-term increases as a result of individual storm events are unlikely. We expect that the effects of precipitation during storm events or spring melting will be attenuated over a long period of time, so that pond sizing becomes a function of average precipitation rates over a long period of time, rather than storm precipitation rates.

- *Hydraulic Storage Depletion:* The reduction of inflow due to the cover/cap and the perimeter diversion channel will lower the steady state groundwater levels within TP-1, which in turn will reduce the seepage at the toe of TP-1 as the tailing pile drains. The reduced toe seepage will reduce the flows to the holding pond. However, the holding pond sizing calculations consider the initial, (i.e., maximum), inflows to utilize a conservative sizing basis.

- *Contingency Factor*: For costing purposes, all holding pond sizing calculations are increased by fifty percent (50%) to account for uncertainty related to long-term discharge rates.

The following equation is used to determine the average effluent flow rate along the toe drain:

$E = (IA/T)7.48 gal/ft^3 + G$, where

E = Effluent flow rate (gpm)

I = Infiltration (ft): Average precipitation at Union Village Dam is 35 inches (2.92 ft)

> Depending of the remediation alternative selected, various infiltration amounts are used. For example, infiltration of zero-inches is used for Alternatives 2B/2C because a RCRA cap is proposed as the cover for the tailings pile. Therefore, the flow rate is assumed to be strictly a function of ground water contribution (5-10 gpm).

A = TP-1+TP-2 Area (ft^2)

> T = Detention Time (min): The detention time is assumed to be 182.5 days (½ year [263,000 min]). There are periods of time during the year, particular spring and late fall, where the highest discharge rates are expected. Assigning a detention time of ½ year has the net effect of increasing the calculated discharge rate by 100% over the annualized discharge rate, thus providing a measure of conservatism in final sizing determination.
>
> G= Ground Water Contribution: A nominal ground water contribution is expected even after the surface water diversion channels are installed around the perimeter of TP-1 or TP-2: This contribution is estimated at 5-10 gpm.

Sizing Considerations for TP-3

The holding pond below TP-3 will receive mostly storm water runoff from the TP-3 area. The amount of runoff will vary depending on how much of TP-3 is removed (if any). Discharge from the holding pond will be dictated by the capacity of the passive treatment systems. The passive treatment systems capacity is estimated to range as high as 40 gpm. The TP-3 holding pond was sized using the 100-year 24-hour storm event (5.65 inches). Details of the system will be addressed during the design stage. Three analytical methods were used to develop sizing estimates:

- *Correlation with USGS-Gauged Watersheds*: Damariscotta (1999) used the Sleepers River Experimental Watershed (W-9) in Danville, Vermont, where extensive flow data have been collected, as a calibration standard for expected flow from the Copperas Brook basin.
- *USDA Storm Water Flow Model – TR55*
- *Runoff Calculations Assuming Minimal Infiltration and Retention*

Sizing results for TP-1, TP-2, and TP-3

The results that were calculated by each of these methods were averaged to provide the runoff volume used in this analysis. As a contingency, the total volume of the holding pond was then increased by 50% to account for uncertainty in the estimate. The sizing table below assumes a six-foot deep pond in all cases. Various options for TP-3 are considered in the following table to provide a sensitivity analysis.

Remediation Alternative	Holding Pond Size (Acres)			
	TP-1/TP-2 All Options	TP-3 Option 1	TP-3 Option 2	TP-3 Option 3
Alternative 2B – RCRA Cap on TP-1/TP-2	0.04	1.0	0.60	0.31
Alternative 2C– RCRA Cap on TP-1/TP-2	0.04	1.0	0.60	0.31
Alternative 3B – 42-inch Soil Cover; TP-1/2	0.07	1.0	0.60	0.31
Alternative 3C – 6-inch Soil Cover, TP-1/TP-2	0.10	1.0	0.60	0.31
Alternative 3D –Hardpan Cover, TP-1/TP-2	0.04	1.0	0.60	0.31

Semi-Passive Alkalinity Doser (SPAD)

A Semi-Passive Alkalinity Doser (SPAD) unit is proposed to reduce the acidity and the high iron/aluminum content of the AMD from TP-3. SPAD is a proven technology for the semi-passive treatment of AMD. SPAD technology involves a two step process:

- Step 1: The addition of calcium (CaO) or sodium based alkaline reagents ($NaOH$) to reduce the acidity of the contaminated water and
- Step 2: The precipitation of metals in a sedimentation basin.

The SPAD requires mechanical parts to deliver the neutralizing reagent and requires a storage tank for the bulk reagent. A SPAD system often includes a water wheel that is driven by the energy of the water moving through the system and a tank with a flushing device. A SPAD provides the ability to control the addition of the neutralizing reagent based on the flow of contaminated water and is considered a lower cost method for achieving acidity reduction than other more active approaches.

For TP-3, the SPAD system will be designed for either 20 or 40 gpm flows. Cold weather and dry conditions represent challenges to the SPAD technology that will be addressed during design.

EPA guidance document: *Design Manual: Neutralization of AMD, Office of Research and Development* (1983) is often used to guide the design of a SPAD system. The aluminum and iron hydroxide sludge that is generated through the addition of the neutralizing reagent is collected in a settling pond. The material may then be allowed to dry to a solid for disposal or collected as a sludge and shipped for disposal.

It is uncertain as to whether the dried solid or bulk sludge would be classified as a hazardous waste or a solid waste. The most costly case is disposal of hazardous sludge. If the material is disposed as a non-hazardous solid, the disposal costs decrease dramatically. The settling pond for the sludge generated by the SPAD is assumed to provide one year of storage for a 3% solids sludge and 24 hours of retention during the peak flow. It is assumed in the EE/CA that sludge would be removed for drying or shipment twice each year.

Anoxic Limestone Drain

An Anoxic Limestone Drain (ALD) is proposed for TP-1/TP-2 passive treatment system to treat the AMD at the base of the toe drain. This unit consists of a buried trench filled with crushed limestone. As anoxic (low oxygen content) contaminated water flows through the ALD from the toe of TP-1, limestone is dissolved within the trench, thus adding alkalinity to the acidic water (Gazea, et al*.*, 1996). The pH is raised accordingly, such that precipitation of dissolved metals occurs after the water exits the drain. The low dissolved oxygen and low aluminum concentrations in TP-1 seeps indicate that this technology will be effective in adding alkalinity to the seep water. The dissolved oxygen and aluminum concentrations are too high in the TP-3 AMD to make construction of an ALD feasible for this area.

The water seeping from TP-1 and TP-2 would be piped into the ALD before it has been exposed to the atmosphere. The AMD impacted seepage passes through a limestone layer, typically three feet thick. The limestone layer is overlain by 10 to 20-mil plastic sheeting, followed by a geosynthetic fabric to prevent puncturing of the plastic. The fabric is then covered with compacted clay. The plastic and clay are emplaced to inhibit the infiltration of atmospheric oxygen. Clay is then covered by native soil. The clay should be three feet thick. The surface of the ALD should be mounded to inhibit surface water infiltration and to accommodate long-term subsidence as the limestone dissolves. The outflow pipe is installed at the top of the limestone trench and is equipped with an air trap to prevent oxygen migration into the drain. Ideally, the limestone layer should be fully saturated at all times. ALD effluent will be discharged to the holding pond.

Sizing Considerations

At the TP-1 treatment area, an ALD would be installed prior to the holding pond to increase alkalinity. For costing purposes, the preliminary design assumes a length of 400 feet. To achieve this size in the TP-1 area, the trench must be constructed in an east-west fashion, parallel to the toe of the tailings north slope.

Successive Alkalinity Producing Systems (SAPS)

Successive Alkalinity Producing Systems (SAPS) are components considered for the TP-1/TP-2 passive treatment system, but not for TP-3. The SAPS design utilizes the sulfate reduction processes and alkalinity generation of anaerobic wetlands and ALDs to remove metals from mine water, while greatly increasing the alkalinity production beyond the capabilities of either of the two systems working alone.

In a SAPS, the decaying organic layer “de-aerates” the AMD and reduces ferric iron (Fe^{+3}) to ferrous iron (Fe^{+2}), converting a previously oxidized AMD to an anaerobic state. This is necessary to allow the anaerobic dissolution of limestone, which also occurs in an ALD. Exposing limestone to ferric iron in solution causes an armoring condition that quickly blinds the limestone surfaces and severely limits the dissolution rate. Thus, it is important to reduce ferric iron to the ferrous state to prevent armoring in a SAPS unit.

The ultimate goal of SAPS is to add alkalinity so that the AMD is buffered against pH drops when the iron is ultimately hydrolyzed and precipitated as a hydroxide. The presence of aluminum in the AMD is problematic for SAPS because the geochemical conditions formed in them favor the formation of the mineral Gibbsite [Al $(OH)_3$], which is a gelatinous solid. The Gibbsite sludge tends to fill the void spaces between the limestone rock used in a typical SAPS and becomes a major maintenance problem. Aluminum can be tolerated in minor amounts by SAPS units, but periodic flushing of sludge from the unit (about once every quarter) may be required to maintain cell effectiveness.

SAPS treat AMD through a combination of an organic substrate layer and a crushed limestone layer. A typical SAPS is constructed within a lined earthen pit. Typical components of the SAPS are a three-foot column of water, underlain by two-feet of organic substrate, and three-feet of gravel-size limestone. Metal removal is principally achieved through reduction reactions in the organic substrate layer, resulting in the removal of dissolved oxygen and biologically-mediated precipitation of metal sulfides through the reduction of sulfate. While iron is the principal metal removed, the anaerobic conditions present in the organic layer are also conducive to the removal of aluminum, cadmium, copper, and zinc. The water flows downward through the organic layer to the underlying limestone where additional alkalinity is generated.

Sizing and Performance Considerations

Aluminum hydroxide precipitation can result in clogging of the limestone substrate, particularly where aluminum concentrations exceed 40 mg/L (Hyman, 2000, Personal Communication). For this reason, PVC piping will be installed within and at the base of the limestone layer to facilitate the periodic flushing of the substrate. A design limitation is the effective life of the organic layer and the limestone substrate. The ability of the organic mat to function as a reducing medium will eventually diminish to the point where metal precipitation on limestone will occur, thus reducing the treatment capability of the SAP. When this occurs, the limestone and organic layers will need replacement. Using data from existing SAPS (e.g., Howe Bridge) we anticipate a design life of 15 years. The effective life can be increased if treatment criteria are achieved through a single SAP (assuming two are constructed in series or in parallel).

Guidance for the sizing of SAPS is provided by the Pennsylvania Department of Environmental Protection, Bureau of Mining and Reclamation. Sizing begins with determining the mass of limestone that will be required to meet certain design criteria. The following equation was developed by Hedin and Watzlaf for ALDs , but is also recommended for SAPS:

$$M=Q_{Pbtd}/V_v + QCT/x$$

where,

M = mass of limestone (t)
Q = is the volumetric flow rate (gallons per minute)
$_{Pb}$ = bulk density of limestone (t/m^3)
$_{td}$ = detention time (hrs)
V_v = bulk void volume fraction
C = predicted effluent alkalinity concentration (mg/L)
T = design life (years)
x = $CaCO_3$ fraction of limestone

Volumetric Flow Rate (Q)
The flow entering proposed SAPS is controlled in order to minimize acid shock to sulfate reducing bacteria and maintain a constant head on the organic mat. The principal means of controlling flow into the SAPS is the holding pond. A constant flow rate allows greater predictability for overall performance and O&M (PRSC) costs. Flow rates for the SAPS receiving seep discharge from TP-1 and TP-2 are calculated using the estimated infiltration rate through these tailings piles plus an increment of flow representing base ground water influx. A safety factor equal to 100% of the seepage flow rate is added to the design flow to account for ground water flow that may not be completely cut-off by the surface water diversion channels around the TP-1 and TP-2. Because the cover design for TP-1 and TP-2 varies under each remediation alternative, the flow rate to the SAPS will be different, ranging between 5 to 10 gpm for Alternatives 2B/2C to an estimated maximum flow of 22 to 40 gpm for Alternative 3C.

Bulk Density of Limestone (Pb)
The bulk density of limestone is estimated to be 1.2 tons per cubic yard, based on information provided by a possible vendor located near Burlington, Vermont (Shelburne Limestone Corporation, Essex Junction).

Detention Time (td)
Detention times of 15 hours are typically used as additional detention time in a SAP does not significantly increase alkalinity.

Bulk Void Volume Fraction (V_v)
The bulk void volume is estimated to be 0.3.

Predicted Effluent Alkalinity (C)
The predicted effluent alkalinity is estimated to be 200mg/L of $CaCO_3$ equivalent. Seeps at the base of TP-1 range in alkalinity as $CaCO_3$ from 2.45 to 120.1, with an average of 52 mg/L (USGS, 1998). The alkalinity as $CaCO_3$ at the base of TP-3 is 0 mg/L (USGS, 1998). The acidity of these waters is about 1,300 mg/L as $CaCO_3$ (Darmariscotta, 1999). An increase in alkalinity to 200 mg/L from similarly acidic waters has been documented (Skousen, et al., undated).

Design Life (T)
A design life of 15 years is used for the TP-1 SAPS. This represents the estimated effective lifespan of the limestone and organic mat.

$CaCO_3$ Fraction of Limestone (X)
The $CaCO_3$ fraction of the limestone is estimated to be 95%.

The table below summarizes the size of the SAP-systems proposed for TP-1/TP-2. The SAP system is designed as two SAPS in parallel. This design offers a certain degree of redundancy to ensure that effluent attainment goals, including reducing acidity, increasing alkalinity, Fe^{+3} precipitation, and sulfate reduction, are achieved. The dual SAP system allows for periodic maintenance without shutting-off the treatment process.

Remediation Alternative	SAP Size (Acres)
	TP-1/TP-2
Alternative 2B – RCRA Cap on TP-1/TP-2	0.48
Alternative 2C– RCRA Cap on TP-1/TP-2	0.48
Alternative 3B – 42-inch Soil Cover; TP-1/TP-2	0.77
Alternative 3C – 6-inch Soil Cover, TP-1/TP-2	0.97
Alternative 3D –Soil/Hardpan Cover, TP-1/TP-2	0.49

Sulfate Reducing Bioreactors (SRBs)
Sulfate Reducing Bioreactors (SRBs) are proposed for the TP-3 AMD passive treatment system at the Elizabeth Mine. An SRB unit is an anaerobic cell that fosters the activity of sulfate reducing bacteria.

The SRB is designed to remove base metals (such as Cu, Zn, Pb, Co, Cr, Cd, Ni, etc.) as metal sulfides in a reducing environment. This technology is well established in pilot programs around the world and in a smaller number of full-scale treatment systems. As a relatively new technology, the available systems for review have been in operation for only 5 to 6 years. Results to date show promise for effective performance over significant periods of time (calculations suggest performance of 20 years or more is possible if sized and constructed correctly).

Anaerobic cells are appropriate for this application because they remove heavy metals from low to neutral pH AMD. Typically, anaerobic cells can raise pH as biologically produced bicarbonate ion (by SR bacteria). Dissolved metals are then precipitated in a subsequent aerobic cell (as a hydroxide) in the cases of a SAPS or an ALD.

An SRB cell is typically comprised of a relatively homogeneous layer of organic material and crushed limestone (called substrate) placed above a drainage/collection layer. This organic substrate layer is the "reaction zone" where the sulfate reducing bacteria function. Like a SAPS, the flow is vertically from the top of the substrate to the bottom. The substrate is totally saturated with AMD. The substrate surface can be either exposed to the elements, underwater, or even buried for this application.

SRB cells use the controlled decay of organic matter to achieve slightly geochemical goals. SRBs utilizes the organic matter to strip dissolved oxygen from the AMD and create anaerobic geochemical conditions. In addition, the SR bacteria use the organic matter as a nutrient source that supports their biological activity. The SR bacteria also require sulfate as a nutrient. Sources of SR bacteria include mushroom compost, most sources of domesticated animal manure, and soils in the anaerobic zones of natural wetlands. Domestic sewage sludge is typically too sterile to be an effective source of sulfate reducing bacteria. Organic matter sources include forestry waste (sawdust and wood chips), agricultural materials (alfalfa, native hay and straw); SR bacterial inoculum can also be a source of organic matter.

The processes by which SR bacteria remediate AMD do not involve the uptake of metals or acidity by the cells themselves. The by-products of cell metabolism are responsible for the improvements in AMD chemistry. The SR bacteria life-cycle reactions involve the generation of the following:

- Sulfide ion (S^{-2}) or hydrogen sulfide (H_2S) gas, which combine with dissolved metals to precipitate sulfides, and
- Bicarbonate (HCO_3^-) or carbon dioxide (CO_2), which raise the pH of the effluent.

The sulfate reducing bacteria appear to facilitate the above through the following reaction:

(Equation 1) $SO_4^{-2} + 2\ CH_2O \Rightarrow S^{-2} + 2\ HCO_3^- + 2\ H^+$

The dissolved sulfide ions combine with dissolved metals to precipitate those metals as sulfides, essentially reversing the reactions that occurred to produce AMD. For example, the following reaction occurs for dissolved zinc, forming amorphous zinc sulfide (ZnS):

(Equation 2) $Zn^{+2} + S^{-2} \Rightarrow ZnS$

The sulfate reducing bacteria perform best at a pH of 5.0 or above, which they can self-maintain through the production of bicarbonate ion. For insurance, the SRB cell will include a crushed limestone component mixed in to protect the sulfate reducing bacteria from acidity excursions in the AMD being treated.

While the precise mechanisms have not been completely identified, the precipitation of Gibbsite must be avoided in SRB cells. It is suspected that unidentified alternative aluminum compounds will form in the SRB cells instead of Gibbsite. These compounds are less prone to plugging. When aluminum is present, ponding the AMD on top of the SRB cell has been found to be the best approach to preventing premature Gibbsite formation.

The anaerobic cell will operate in harsh weather conditions. Reisinger and Gusek (1999) reported on the operation of a pilot sized SRB cell at an elevation of 9,500 feet at an underground copper mine site in south central Wyoming. This cell functioned in sub-freezing conditions at water temperatures as low as 0.2 °C. While SR bacterial activity slowed during the winter monitoring period, it was still sufficient to provide effective treatment. The physical action of ice formation on the poorly insulated side of the test cell was more problematic than the modest reduction in bacterial activity. This problem was subsequently solved in a second pilot SRB cell that was completely buried; the 10 feet of snow at this site provided additional insulation during the winter months.

The longevity of an SRB cell will be governed by the exhaustion of the “reservoir” of organic carbon that was installed when the cell was built. Two molecules of organic carbon are stoichiometrically required to reduce a molecule of sulfate (see Equation 1 on the previous page). Sulfate reducing bacteria can typically reduce sulfate (to sulfide) at a rate of 0.3 moles per day per cubic meter of cell volume. The rate decreases slightly during the winter.

Typical cell designs have been based on carbon consumption rates estimated in pilot scale SRB cells. Cell longevity values on the order of 25 to 30 years have been estimated. But due to the relative novelty of the design concept (the oldest operating large scale SRB system in Missouri is only five years old), actual cell longevity on this order has not been directly observed. However, one volunteer passive treatment system outside an abandoned metal mine that has operated unattended since about 1889 (Gusek, Personal Communication, 2002), has been identified in Ireland. This volunteer passive treatment system reportedly has 70% of its total metal removal capacity remaining.

The goal of an SRB is to immobilize metals as sulfides. A concern exists over metal accumulation in the substrate that would cause this material to be classified as a hazardous waste. Limited experience has shown that SRB substrate is non-hazardous, if it is allowed to "age" for several weeks after exhumation. If this was found to not be the case, the substrate materials could be leached in situ and the metals stripped out and recovered prior to exhumation to produce a non-hazardous material suitable for sanitary landfill disposal.

The reaction shown in Equation 1 shows the generation of sulfide ion (S^{-2}) which can under certain geo-chemical situations produce hydrogen sulfide gas, which is particularly odorous. Odor control is achieved by carefully balancing the metal loading and sulfate reduction rates (Equations 1 and 2) in the SRB cell so that excess hydrogen sulfide is minimized. While sulfate reduction rates may decline in the winter, typically metal loading rates typically decline as well.

The sulfate reducing bacteria will also produce excess alkalinity in accordance with Equation 1. This excess alkalinity is very beneficial in that it is available to neutralize AMD that may need to be diverted around the SRB cells in storm event situations that are outside the system design criteria.

The discharge from an anaerobic cell is typically devoid of dissolved oxygen and may contain dissolved organic matter that can further consume oxygen. Thus, anaerobic cell discharge is typically polished in an aerobic cell, such as an aerobic wetlands.

Water exiting the SRB is then oxygenated for the polishing step to effectively remove manganese, zinc, and any remaining metals that escape the SRB. The site topography below TP-3 lends itself well to a high gradient flow channel from the SRB to an aerobic wetland constructed at the uphill side of TP-2. Water flow down this rock channel (granite/limestone mix) will result in oxygenation during all seasons.

Sizing Considerations

The SRB cell design for TP-3 is based on a flow rate of 40 gpm at 0.4 acres, and 20 gpm at 0.2 acres; the substrate would be about 3 feet deep. The cell could potentially last from 20 to 25 years before the substrate would need to be replaced; the substrate comprises about 40% of the cell capital cost. The SRB system would actually be comprised of two cells, plumbed in parallel. Thus, while maintenance was being performed on one cell, the other cell could continue treatment. The discharge from the SRB cells would pass through an aerobic cell less than 0.25 acres in size. This cell would actually be a cascading channel leading down to the aerobic wetlands.

To accommodate cold weather concerns, the entire SRB will be constructed below the frost line with insulating construction materials overlying the system for easy access and substrate removal or amendment. Channeling and preferential flow is minimal or entirely eliminated in the down-flow design systems, where flow rate is on the order of 12 inches over 24 hours.

For costing purposes, the EE/CA reflects system clean-outs on a cycle of 10 years. System cleanout involves the organic substrate only. Given that the TP-3 runoff contains cadmium and other metal concentrations, it is assumed that the organic material is a hazardous waste once removed from the SRB at 10-year cycles. Disposal costs would be reduced if the material is determined to be a non-hazardous waste.

Aerobic Wetlands

Aerobic wetlands are proposed for use to treat AMD runoff from both TP-1/TP-2 and TP-3 following the sulfate reducing systems (SRB and SAPS). Wetland ecosystems will raise the pH of acidic waters and will remove metals from AMD through a variety of mechanisms. Metal removal occurs in wetland systems through various mechanisms. Gusek and Wildeman (1995) describe the following major processes:

- Filtering of suspended material
- Ammonia-generated neutralization and precipitation
- Adsorption and exchange with plant, soil and other biological materials
- Metal uptake into live roots and leaves
- Hydroxide precipitation catalyzed by bacteria in aerobic zones
- Sulfide and carbonate precipitation catalyzed by bacteria in anaerobic zones

Constructed wetlands typically consist of one or more wetland cells; each cell is a shallow basin or channel through which the contaminated water flows to be treated. An impermeable liner along the bottom and sides of the cell provides a barrier to seepage of contaminated water into the surrounding environment. Inlet and outlet structures at opposing ends of the wetland cell are designed to optimize distribution of the wastewater throughout the cell. Wetland cells are generally designed to be plug-flow systems, where the wastewater entering at a certain point can be assumed to spend a certain amount of time within the wetland for treatment before exiting as treated effluent. The amount of time that a given quantity of water spends in the wetland is the hydraulic retention time (HRT) of the wetland cell. This parameter is important for design and for determining the effectiveness of the wetland system in removing contaminants. (Reed, et. al., 1995)

Aerobic wetlands are designed with large surface area to volume ratios to promote contact of water with the atmosphere. Treatment is provided through oxidation of ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}) which then forms ferric hydroxides and oxyhydroxides through hydrolysis. The reaction rate is partially pH-dependent, with the rate decreasing with lower pH (Robinson, 1997). A shallow soil layer (<30 cm) is placed on the bottom of the wetland to provide a growth substrate for macrophyte vegetation (Gusek and Wildeman, 1995).

For TP-3, oxygen-rich water will enter the aerobic wetland treatment cell, where rock channels and algae mats are designed specifically for Mn removal. Algae incorporate

Mn into a pyrolusite (MnO) “glue” on the rock surface that promotes further Mn and other metal precipitation.

Site specific factors such as the climate, flow rates, and the specific chemistry of the AMD, including pH and contaminant concentrations were considered in choosing both the aerobic wetland type and in developing its design criteria. The SAPs and SRBs discussed above are similar to anaerobic wetlands. As a polishing step to either the SAP or SRB, an aerobic system is most suitable as the final component of the passive treatment system at the Elizabeth Mine for TP-1/TP-2 and TP-3. Sulfate reduction in the SAPS or SRB is expected to be the primary metals removal step for most metals. The aerobic wetland is designed to reintroduce oxygen to the treated water and remove any remaining metals that may be above discharge criteria.

Plant roots may serve as a local site for both adsorption and/or metal precipitation. As the wetland plants mature, portions of the root material are discarded causing adsorbed metals to become part of the organic sedimentation and bottom sludge of the wetland (Reed et. al., 1995). Uptake of metals by plants (or absorption) is a less significant means of removal, as has been presented by a number of studies over the past decade, including a relatively recent study by Mitsch and Wise (1998). Thus, above water, plant biomass tends to retain fairly low concentrations of heavy metals, while the sediment material of the wetland tends to accumulate metals. This is significant because it may lead to the need for dredging wetlands that have been exposed to relatively high metals loading as a part of maintaining operations.

The aerobic wetlands are planned for BOD and manganese removal (TP-3) with a "combination of rock filters and algae mats." Manganese oxidation will occur by contact with algal mats of leptothrix discophora algae. The wetland will have rock cobbles on the bottom to provide the surfaces for the algae to attach and grow. The algae require exposure to sunlight and if the plants grow and multiply they will shade the water surface, and without sunlight the algae will die, therefore maintenance activities may include the harvesting of plants that would unacceptable shade the algae. Aquatic plants also die back each fall, resulting in a litter that may also need to be harvested and removed so that it does not smother the algae.

The algae mat for manganese removal is being proposed since the more familiar cattail marsh is not as effective for removal of this metal. The algal mats have been demonstrated in Florida and California and achieved excellent removals of phosphorus and metals. Those systems incorporated frequent algae harvesting because if the algal cell is allowed to die and decompose there is a release of substances back into the water. Algae also require nutrients (ie: nitrogen, phosphorus, etc) to grow and function. It is assumed that the SRB will leak sufficient quantities of nutrients to support the algae.

Sizing and Performance Considerations

Guidance for the sizing of aerobic wetlands is provided by the (former) U.S. Bureau of Mines. The size of the wetland, measured in acres of surface area, is estimated by the following equation:

[Fe loading (lb/day)/180(lb/ac/day)]+[Mn loading (lb/day)/9(lb/ac/day)]+[acidity(lb/day)/60(lb/day/acre)]

Iron Loading: The SAP and SRB systems are very effective at retaining iron in organic substrate. As a result, the iron species in the effluent will be significantly reduced before discharge to the wetland. For example, the Howe Bridge SAP in Pennsylvania has reduced iron by 50%, and even higher removal rates have been documented (Skousen, et. al., undated). For conservative estimation purposes, it is assumed that only 50% of the iron would be retained in the primary passive treatment system component (SAP or SRB), with the remainder discharging to the wetlands. Seeps at the toe of TP-1 have iron concentrations ranging from 101 mg/L to 747mg/L in recent sampling events. We assumed an average seep concentration of 462 mg/L. Iron concentrations at the TP-3 area range from 70.7 mg/L to 106 mg/L, with an average concentration of 88 mg/L.

Manganese Loading: Manganese concentrations have been measured between 2 mg/L and 6 mg/L. It is assumed that 50% of the manganese load would pass thought the primary passive treatment system component into the wetland.

Acidity Loading: The acidity of the seeps at TP-1 and stormwater runoff at TP-3 is approximately 1300 mg/L as $CaCO_3$. The estimated acidity loading will be approximately 780 mg/L. A safety factor of 50% was applied to the calculated size of the wetland in order to account for uncertainties associated with the loading assumptions. The sizing equation described above was developed for Abandoned Mine Lands (AML) compliance. According to the Pennsylvania DEP, NPDES effluent limits are generally more conservative than AML criteria. Therefore, as a "rule-of-thumb", standard practice is to create a wetland twice as large as suggested by the AML sizing calculation to meet NPDES criteria.

Remediation Alternative	**Wetland Size (Acres)**		
	TP-1/TP-2	**TP-3 Option 1**	**TP-3 Option 2/3**
Alternative 2B – RCRA Cap on TP-1/TP-2	1.6	1.0	0.8
Alternative 2C – RCRA Cap on TP-1/TP-2	1.6	1.0	0.8
Alternative 3B – 42" Soil Cover, TP-1/TP-2	2.5	1.0	0.8
Alternative 3C – 6" Soil Cover, TP-1/TP-2	3.2	1.0	0.8
Alternative 3D – Hardpan Cover, TP-1/TP-2	1.6	1.0	0.8

Experience in cold weather systems in the western states and central Appalachians suggests good performance during winter months if designed correctly. The design will address cold weather performance concerns in Vermont, where extended periods of cold weather with no snow cover are possible. Clean-out of the aerobic wetland is not expected to be necessary (or desirable) for periods of 20 to 30 years. For costing purposes, we have assumed clean-outs every 15 years. Water exiting the aerobic cell must meet applicable water quality criteria.

3.3.2.2 Slope Stabilization Technologies

A preliminary geotechnical engineering evaluation was performed as part of this EE/CA to assess the stability of the existing tailings. The cursory analysis identified critical areas with respect to stability. TP-1 has the most extensive area of steep slopes and the preliminary analysis suggests that these slopes could fail at high groundwater levels or under earthquake loading. Thus, the design will need to more fully evaluate the stability of the slopes of TP-1 and TP-2 as well as the entire area of TP-3. If the design indicates that the slopes of TP-1, TP-2, or TP-3 do not have an adequate level of stability, the current slopes may be modified to achieve an acceptable level of safety. In addition to the stability of the waste material currently in place at the Site, the placement of cover materials such as a geomembrane or low permeability soil may also requires the establishment of a slope grade that will result in a factor of safety above 1.5 for the cover system. A Factor of Safety (FS) in stability assessments reflects the level of stability of a slope where the driving forces exceed the forces resisting a landslide. A FS greater than one means that the resisting forces exceed the driving forces. In order to ensure an adequate level of stability, engineered slopes generally aim to have FS greater than 1.3 to 1.5.

A preliminary evaluation of the FS for the slopes of TP-1 indicates that regrading the slope to a surface with a 1:3 vertical to horizontal ratio (after regrading), results in an acceptable Factor of Safety. The estimated FS against shear slide for this alternative are estimated as 2.8, 1.3, and 2.3 respectively for the existing ("low") groundwater level, "high" pore pressures (a 100-year storm), and the existing ("low") ground water level plus earthquake loading. All of the alternatives in the EE/CA include a requirement for a thorough geotechnical data gathering effort and associated geotechnical design evaluations to determine the measures that may be required to achieve a stable slope configuration. If necessary, slope stabilization would be accomplished through the most practical technique that meets the project objectives of minimizing erosion, long-term effectiveness in reducing AMD, and historic preservation. The most likely techniques are re-grading, reinforcing, or buttressing, however, other techniques will be evaluated during the design.

3.3.2.3 Caps/Covers

Hydraulic isolation of tailings will prevent water and oxygen from entering the tailings from the top and sides, thus reducing erosion and leachate generation. A surface water diversion channel is included in all Alternatives. This diversion channel will be designed to intercept all run-on and shallow groundwater that is currently entering TP-1 and TP-2.

To complete the isolation of TP-1 and TP-2 from water and oxygen (and subsequent AMD formation) a cover is needed to limit the amount of direct infiltration (rain/snowmelt) from entering the tailings. All of the cap/cover systems presented are intended to support vegetation, improve aesthetics, provide a stable surface over the tailings, and prevent direct human exposure to the tailings.

A geomembrane cap is the primary component of Alternatives 2B and 2C. A soil cover is the primary component of Alternatives 3B, 3C, and 3D. All cover systems (geomebrane caps and soil covers) will be installed with surface grades that promote run-off and prevent ponding of water on the ground surface or on the geomembrane.

Geomembrane Caps:
In accordance with USACE (1994), Rast (1997), and EPA (Gagne and Choi, 1997, 2001), the multi-layer cap system should include the following layers:

Top Cover – The top cover layer (usually vegetation) protects the underlying layers from water and wind erosion and dehydration. Typical design options for the top cover include vegetative cover, rock or gravel, and polymeric liner. Vegetative cover is the most common top cover used to protect the underlying layers and is recommended at the Elizabeth Mine. The design of the vegetative cover involves: (a) selection of suitable plant species, (b) seedbed preparation, (c) seeding /planting, (d) mulching and/or chemical stabilization, and (e) fertilization and maintenance. The type of top cover can be integrated with the final Site use plan.

Soil Cover – The soil cover provides root support for the vegetative cover. It must have sufficient thickness to protect the underlying liners from vegetative root disturbance and frost (if necessary). The minimum top layer (topsoil and additional soil) suggested by the EPA is 24 inches for caps with a drainage geocomposite layer (EPA, Choi, Personal Communication, 2001). The topsoil layer is typically at least six inches in thickness and is composed of soil and other material suitable to support organic growth. The remaining soil is often common borrow with a gradation determined by the design. Alternative materials, (compost, wood chips, etc.) will be evaluated for use in the topsoil layer. More detailed evaluation will be performed during design to determine if a reduced thickness of this layer would be acceptable in order to reduce truck traffic. The EE/CA assumes that an 18-inch soil cover is acceptable for Alternatives 2B and 2C.

Filter Layer – The filter layer separates the soil cover layer from the drainage layer, thus preventing soil layer fines from clogging the drainage layer. Typically, the filter layer is made up of sand, gravel, and/or geotextiles. This layer would only be necessary if a soil/gravel drainage layer was selected as a component of the cap.

Drainage Layer – The drainage layer provides a controlled outlet for the water that flows through the soil and would otherwise pond above the barrier layer. The drainage layer plays a critical function in minimizing the saturated thickness of the soil to improve the stability of the soil and reduce the potential for water to enter any holes or cracks in the barrier layer. Material options for the drainage layer include drainage geocomposites, sand, and gravel. A drainage geocomposite is recommended for use at the Site.

Low Permeability Layer – The low-permeability layer sits below the drainage layer and prevents the flow of water into the tailings. A two component low permeability layer is often installed to provide a backup in the event the primary layer is punctured, degrades, or cracks. The primary low permeability layer is expected to consist of a geomembrane (at least 40 mil). PVC, HDPE, or LDPE can all be used as the synthetic material in the primary barrier layer. The geomembrane is usually smooth, however, texture can be added to improve the friction angle (stability) on slopes. Geomembrane sheets are heat welded together to form a continuous barrier layer. The secondary barrier layer can be a thin panel of bentonite sandwiched between two fabric layers or 12 inches of soil with a permeability of no greater than 1×10^{-5} cm/sec. Since the Vermont Solid Waste Regulations only require a single barrier layer, the need for the secondary barrier layer will be evaluated during design. A secondary barrier may be appropriate sincethe design life of the cover needs to consider that water and oxygen will need to be prevented from entering the tailings in perpetuity.

3.3.2.4 Alternative Cover Layers

Two alternative cover designs were evaluated as part of the EE/CA.

Evapotranspiration Covers (Alternative 3B)

Evapotranspiration (ET) covers are soil covers with an engineered vegetative covering that encourages water storage and enhances evapotranspiration. The evaporative depth of an ET cover mainly depends on the soil type of the bottom compacted soil layer. For a soil type between silt and clay, the average evaporative depth is 19 to 42 inches (assuming a six-inch top vegetative soil cover). For the Elizabeth Mine ET cover, a 36-inch soil thickness was used, with a six-inch topsoil layer. For ET covers:

- The evaporative zone depth is the maximum depth from which water may be removed by evapotranspiration.
- Where surface vegetation is present, the evaporative depth should at least equal the expected average depth of root penetration. The influence of plant roots usually extends somewhat below the depth of root penetration because of capillary suction to the roots.
- The depth of capillary draw to the surface without vegetation or to the root zone may be only several inches in gravels; in sands, the depth may be about four to eight inches; in silts, about eight to 18 inches; and, in clays, about 12 to 60 inches.

For an ET cover with a six-inch top vegetation layer, we can assume that the root zone (root penetration depth) is greater than six inches. The evaporative depth will mainly depend on the capillary depth of the bottom compacted soil layer:

Compacted Soil Layer	Capillary Depth (inch)	Evaporative Depth (inch)
Silt	8 to 18	> 14 to 24 (average 19)
Clay	12 to 60	> 18 to 66 (average 42)

The 36-inch ET cover was determined through case studies that demonstrated effectiveness at thicknesses of 36 to 42 inches, but limited ET effectiveness at 24 inches or less. These studies, coupled with modeling using EPA's *HELP* model, provide a preliminary ET thickness estimate of 36 inches to achieve effectiveness in Vermont. The ET thickness will be optimized during design if selected by EPA. It is assumed that the bottom 18 inches of the ET cover will be installed to achieve the low permeability requirements of the VTSWMR.

Induced Chemical Hardpan (Alternative 3D)

Induced chemical hardpan capping is a technology that is currently being developed specifically for AMD generated by sulfide-rich tailings and waste rock. Hardpan capping relies on chemical reactions between sulfide waste rock and lime/limestone applied to a tailings pile's surface to create a hardpan layer or cap. The advantage of a chemical hardpan is that it would, in theory, require relatively low maintenance, as the cap is "self-healing," (i.e., when holes or cracks form in the cap and water enters, more capping material is formed by the chemical reaction) (Chermak and Runnells, 1996). However, the limestone may need to be periodically re-applied to maintain the cover.

This form of chemical capping requires direct contact between tailings and limestone (or crushed lime), to cause the formation of a "low-permeability" gypsum and iron oxide hardpan layer. The following reactions, as presented by Chermak and Runnells (1996), show the general behavior of the system:

Pyrite/pyrrhotite dissolution:

$$FeS_2 + 7/2O_2 + H_2O \rightarrow 2SO_4^{2-} + 2H^+ + Fe^{2+}$$

calcite dissolution and gypsum precipitation:

$$SO_4^{2-} + CaCO_3 + 2H^+ + H_2O \rightarrow CaSO_4 \bullet 2\,H_2O + CO_2$$

iron oxyhydroxide precipitation:

$$Fe^{3+} + 2\,H_2O \rightarrow FeO(OH) + 3H^+$$

Laboratory testing of hardpan formation performed by Chermak and Runnells showed that when lime is applied, hardpan formation improves with increased fresh (unoxidized) sulfide content. Ettner and Braastad (1999) demonstrated the use of hardpan cap construction for a tailings impoundment in Roros, Norway. After one year, an induced hardpan layer was found to reduce the hydraulic conductivity of the tailings. Their field tests demonstrated that hardpan formation is possible at shallow depths in deeply oxidized tailings and under extreme climatic conditions. Concerns remain, however, regarding the limitations of hardpan effectiveness. Demonstrations to date have not reported on the uniformity of the hardpan layer; however, they have reported decreases in vertical hydraulic conductivity approaching two orders of magnitude. The long-term stability of the hardpan also remains in question in a dynamic environment, where precipitation and dissolution of secondary minerals (such as gypsum) is a continuous geochemical phenomenon. Hardpan layers also may be susceptible to mechanical erosion on slopes and are, therefore, not recommended to stabilize the slope areas of tailings.

<u>Induced Hardpan References</u>:

Chermack, J.A., D.D. Runnells. "Development of Chemical Caps in Acid Rock Drainage Environments". *Mining Engineering*. June 1997, p. 93-97.

Chermak, J.A. and D.D. Runnells. "Self-Sealing hardpan barriers to minimize infiltration of water into sulfide-bearing overburden, ore, and tailings piles." *Tailings and Mine Waste '96: Proceedings of the Third International Conference on Tailings and Mine Waste '96/Fort Collins/Colorado/USA.* Rotterdam: A. A. Balkema, 1996.

Ettner, D.C. and Braastad, G. , "Induced hardpan formation in a historic tailings impoundment, Roros, Norway". Tailings and Mine Waste, 1999; *Proceedings of the Sixth International Conference on Tailings and Mine Waste '99/Fort Collins/Colorado/USA;* Balkema, Rotterdam, Netherlands .

Appendix B contains supporting material for the EE/CA which includes stability and analysis of tailings slopes, abandonment of subtailings drainage pipes, environmental concerns during response activities, and access and egress to the Site.

3.3.2.5 Tailings Pile 3 (TP-3)

The historical significance of TP-3 has been the subject of ongoing discussions and concerns by local citizens and the Vermont State Historic Preservation Officer (SHPO) from the outset of EPA's involvement at the Elizabeth Mine. Discussions between EPA, the VTANR, and the SHPO, led to the design of EE/CA cleanup alternatives that attempt to minimize the impact of the cleanup on this valuable historic resource. The preservation of TP-3 requires a balancing of costs and historic preservation. The State of Vermont is responsible for 100% of the operation and maintenance costs (PRSC) associated with any treatment system that will be installed to treat the run-off from areas of TP-3 designated for preservation. From the environmental cleanup and cost minimization perspective, complete removal of TP-3 would be the prefered approach. However, the historic value of this resource requires a serious evaluation of options that could preserve or minimize impacts to this resource, recognizing that significant PRSC costs will be incurred by the State on an annual basis in perpetuity.

All cleanup options considered in this EE/CA presume preservation of some portion of TP-3. Figure 3-1 contains a plan view of TP-3 showing Option 1, complete preservation. Figure 3-2 contains a plan view of Option 2. Option 2 involves the removal of the high sulfide and metal content areas of TP-3. The removal of this material will reduce the volume of flow that will require treatment and reduce the acid and metal loading to the passive treatment system. It is more likely that a cost effective treatment system can be achieved with this material removed. Figure 3-3 contains a plan view of Option 3. Option 3 preserves a portion of the Copperas Works below the Town Road, with the intent of further reducing passive treatment system costs and improving the likelyhood of successful performance in meeting water treatment objectives.

The VTANR has stated that the current intent is to preserve all of TP-3 as part of the cleanup. The position is qualified by the following:

- The design and associated pilot studies must establish that the run-off from TP-3 can be treated to meet acceptable discharge standards; and
- The costs associated with preservation of TP-3 are provided as an increase in the current funding to VTANR.

At the time of the final design, EPA will provide VTANR with a revised PRSC cost estimate for the TP-3 preservation Options, as well as the performance data from the pilot studies. VTANR will be requested to make a final decision regarding TP-3 at that time. EPA will adjust the final design in accordnace with the VTANR determination. VTANR may, at that time, determine that preservation of TP-3 is not a viable option from a financial or technical perspective.

3.3.3 Alternative 2B – Hydraulic Containment with removal of TP-2

3.3.3.1 Objectives

The objective of Alternative 2B is to isolate the tailings material within TP-1 and TP-2 from interaction with water and oxygen, thereby eliminating (or significantly reducing) the generation of AMD from this material. This Alternative is also designed to minimize the long-term operations and maintenance costs of the TP-1 passive treatment system by reducing the flows at the seeps of TP-1 to the greatest extent possible. Alternative 2B is designed to stabilize tailings piles, limit erosion and transport of tailings material, reduce surface water and oxygen infiltration into tailings and prevent clean surface water from flowing onto the tailings.

3.3.3.2 Detailed Description of Alternative

To accomplish the objectives presented in Section 3.3.3.1 above, Alternative 2B reduces the footprint of the tailings by removing TP-2 and placing the material on TP-1. This creates a smaller area for maintenance.

Alternative 2B consists of the following activities and components (see Figure 3-2 for Alternative 2B conceptual drawing):

- Pre-design investigations, including geotechnical studies and pilot testing of passive treatment systems
- Engineering design
- Mobilization and site preparation
- Construct holding ponds
- Construct surface water diversion system
- Slope stabilization, as necessary
- Material re-location
- Construct cap system
- Construct passive treatment systems
- Collect and treat runoff from TP-3 with passive treatment
- Collect and treat seepage from TP-1 with passive treatment

Depending on funding, these activities may be phased, as described in Section 2.0 of this EE/CA. Substantial data gathering, testing, and engineering evaluation will be performed to develop a final design for Alternative 2B. Geotechnical data and evaluations will be used to determine the final surface and slope grades. Pilot testing and chemical analysis will support the design of the passive treatment systems. Hydraulic flow information about the tailings will help to better predict the impact of the cover system on the seeps of TP-1.

Each of the major components of Alternative 2B is described further below.

Material Relocation (Tailings and Waste Rock)
All of TP-2 would be excavated and hauled to TP-1. Tailings materials from TP-2 would be used to fill low-lying portions of TP-1 and help achieve the design-grade requirements for the final cap. A portion of TP-3 may also be removed and consolidated into TP-1, depending upon the final decision regarding TP-3. The exposed areas of TP-3 would be restored to promote vegetation or stabilized with rip-rap.

Grading and Slope Stabilization
The top surface of TP-1 would be regraded to an acceptable slope angle. The design will seek to optimize surface water run-off while minimizing the need for additional soil volume or exposure of the unoxidized tailings. The current slope angle is approximately 1%, from west to east and from north to south. Drainage from the surface of TP-1 would be diverted to the clean-water perimeter diversion channel. The oxide cap covering TP-1 would be retained as much as possible. The slope along the edge of TP-1 is very steep and may require regrading depending upon the final cover design. Stability and infiltration evaluations will be performed during design to determine if a steeper slope along the edge of TP-1 will meet the slope stability performance criteria for the

proposed cover system. A steeper slope would better preserve the historic profile, reduce truck traffic, and minimize the exposure of unoxidized tailings. All of these issues will be finalized during the design.

Geomembrane Cap

A geomembrane based cap will be installed over TP-1 to minimize infiltration into the tailings. The major components of the cap are described below:

Soil layer: This layer provides support for the vegetative cover, protects the barrier layers, and allows for the retention and use of water by vegetation. It will include approximately 6 inches of topsoil and 12 inches of additional soil material. The exact amount of soil will be determined during the design. EPA will try to minimize the thickness of this layer to reduce truck traffic. Alternative cover materials, such as stone, will also be evaluated during design.

Drainage layer: This layer allows for the drainage of water that flows through the soil layer and cannot flow past the barrier layer. A geosynthetic (engineered) drainage layer provides a conduit to carry water off the barrier layer without allowing the water to pond on top of the barrier layer.

Barrier layer: This layer prevents water from flowing into the tailings. The top barrier will be a geomembrane. During design, the need for a second barrier layer will be evaluated. If it is determined to be necessary, the second barrier layer would be a geosynthetic clay liner. The design will also evaluate the need for a barrier layer on the steep slopes. If design studies indicate that an acceptable degree of erosion stabilization and infiltration reduction can be achieved, an alternative cover configuration will be considered for the slopes of TP-1.

The cover system will have a final grade that promotes drainage off the cover and prevents ponding on the primary barrier layer. Figure 3-2 provides a side view of the proposed cap.

Surface Water Diversion

A single diversion channel would be constructed on each side of the combined tailings pile to collect the surface water from the capping system and from the rest of the watershed. Since surface water runoff would never contact tailings material under this scenario, all runoff (except that associated with ground water seeps at the TP-1 toe drain) can be diverted around the base of the capped tailings into the Copperas Brook stream channel. The diversion channels would be constructed to a sufficient depth to collect shallow ground water. The ground water would be intercepted at the margins of the tailings pile and diverted to Copperas Brook. One side of the channel may be lined with geomembrane or other suitable material to limit infiltration into the tailings. Throughout most of the year, the channeled flow through the diversion system would be relatively low. The channels must be designed, however, to handle the flow of a 100-year storm event, assuming minimal infiltration.

Passive Treatment Systems

Passive treatment systems for all Alternatives are described in Section 3.3.2.1. As part of the capping and containment strategy in Alternative 2B, a toe-drain system would be constructed to collect all discharges of ground water from the base of the combined tailings pile. Once the cap and diversion channels are in place, the tailings pile would begin to de-water, but only to a certain point. Ground water influx into the base of the tailings would continue. The design will include studies to determine the ground water contribution to the post-cap flow. Assuming the perimeter diversion channels are successful at intercepting shallow ground water flow, the amount of recharge from the base is likely to be minimal. Currently, a series of five to six significant seeps can be observed during all seasons at the base of the TP-1 north slope. The rate of discharge varies to a small extent (compared to surface water flow) on a seasonal basis. Mid-winter flows are very similar to summer flow rates. Further reductions in seasonal variability are likely, following completion of the Alternative 2B capping and diversion scenario, since the primary contributions to seep flow (surface and shallow lateral ground water infiltration) would be eliminated. For preliminary costing purposes, we have assumed that the long-term flow rate of the combined seeps following cap construction is on the order of 5-10 ten gpm. The current calculated flow at the toe of TP-1 is on the order of 110 gpm.

The seasonal variability in deeper ground water flow in the Copperas Brook watershed, while uncertain at this point, is likely minimal (with the exception of the spring melt).

The components of a passive treatment system considered for possible application at TP-1 include an ALD, a water holding/retention basin(s), a pair of SAPS in parallel or a SRB(s), and an aerobic wetland. The water flowing from the base of the tailings has high concentrations of dissolved ferrous iron and aluminum. Effective treatment through the use of an ALD plus one or two SAPS ponds or SRBs would increase the alkalinity of seep water, remove the iron and aluminum, remove sulfate and remove other metals such as copper and zinc. Finally, the treated water would be discharged to an aerobic wetland, designed as a polishing step to ensure that metals concentrations fall below the established treatment objectives and return oxygen to the water prior to discharge to Copperas Brook. Since storm events under this Alternative would largely discharge clean runoff water around TP-1, there is likely to be little to no effect on flow rates experienced in the toe drain system itself. The toe drain system, ALD, catchment basin(s), buffering system, and SAPS/SRBs would be constructed such that storm water does not mix with and overwhelm seepage water that must be treated. The wetland component of the treatment system would be subject to inundation from large storm events. All drainage systems would be constructed to minimize the effect of these events on wetland functionality.

A separate passive treatment system will be installed for TP-3 (as described in Section 3.3.2.1). The components considered for possible application to TP-3 include: a water holding/retention basin, Semi-Passive Alkalinity Dosing System (SPAD), settling basin for SPAD sludge, drying basin for SPAD sludge, a Sulfate Reducing Bacteria bioreactor (SRB), and an aerobic wetland with algal mats. Accomplishing the treatment of AMD for TP-3 through a passive or semi-passive system appears within reach of existing technologies. The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for copper. EPA expects that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. Data from pilot-scale treatability studies will be used to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal. Nevertheless, it seems quite likely that a passive and/or semi-passive treatment system can be designed for the TP-3 contamination that has a reasonable probability of success.

Detailed analysis of potential passive treatment systems for TP-1 and TP-3 will be performed as part of the design process. Modular systems are envisioned, where additional treatment units can be added to account for periodic higher flow rates. Settling ponds and the aerobic wetland system would be designed with excess capacity to allow for substantially greater flows.

Winter conditions in Vermont will impact the functionality of wetland treatment systems to some extent, especially during deep-freeze periods with little to no insulation from snow cover (typical November and December conditions). Recent studies by Montana Tech (K. Burgher, 2001, Personal Communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged. These issues will be addressed in detail during the design.

Post-Removal Site Control (PRSC)

PRSC represents those activities that must be performed to maintain the effectiveness of the cleanup alternative. The EPA removal authority cannot be used to perform or finance PRSC. It is assumed that the State of Vermont will be responsible for the PRSC at the Site.

For Alternative 2B, PRSC includes the following activities:

- Sampling and analysis of the effluent from the passive treatment systems as necessary to demonstrate compliance with the discharge criteria
- Inspection of cap/cover and passive systems (monthly, then quarterly)
- Periodic sediment removal and repair of diversion channels (as necessary, assumed one-year cycle)

- Periodic cleanout of water retention/holding basin(s) (as necessary, assumed one-year cycle)
- Re-charging of limestone (or equivalent) and organic compost in passive system for treatment of seeps (assumed 10-year cycle for all TP-3 Options and 15 years for TP-1)) and disposal of metal sludge from passive system components
- Periodic cleanout/replanting/repair of wetland (15-year cycle)

Cost

The major costs for Alternative 2B are associated with regrading, capping, building diversion channels, seepage collection system (toe drain), holding pond, passive/natural treatment system, and PRSC. The critical factors associated with the cost of Alternative 2B include the following:

- Location of a borrow source for the soil/cover layer (increased costs with increased haul distance
- Volumes of earth to be moved and regraded
- Management and control of exposed fresh sulfides during construction
- Cost of low permeability liner and drainage geocomposite
- Frequency of passive system cleanout

The total capital cost (direct and indirect) for Alternative 2B range from $13.6 million to $16.2 million. The cost range is based on the three Options for TP-3. See Table 3-3 for a more detail regarding cost.

Annual PRSC for routine maintenance activities of the cap and drainage structures and the TP-1 passive treatment system is $82,000 per year. The annual PRSC for TP-3 varies with the amount of preservation. For complete removal of TP-3 some costs would be incurred to stabilize erosion while the area becomes vegetated. For the preservation of TP-3, the annual maintenance costs are in the range of $153,000 for preservation Options 2 and 3 (see Table 3-4) and up to $400,000 for the complete preservation of TP-3. PRSC for the TP-1 passive treatment system is expected to decrease substantially following cap construction, due to the reduced flow seeping from the source material.

3.3.4 Alternative 2C: Hydraulic Containment (2B, But Retain Current Surface Profile of TP-1, TP-2)

3.3.4.1 Objectives

The objective of Alternative 2C is to isolate the tailings material within TP-1 and TP-2 from interaction with water and oxygen, thereby eliminating (or significantly reducing) the generation of AMD from this material. This alternative is also designed to minimize the long-term operations and maintenance costs of the TP-1 passive treatment system by reducing the flows at the seeps of TP-1. Alternative 2C is designed to stabilize tailings piles, limit erosion and transport of tailings material, reduce surface water and oxygen infiltration into tailings and prevent clean surface water from flowing onto the tailings.

Detailed Description of Alternative

Alternative 2C consists of the following activities and components (see Figure 3-3 for Alternative 2C conceptual drawing):

- Pre-design investigations including geotechnical studies and pilot testing of passive treatment systems
- Engineering design
- Mobilization and site preparation
- Construct holding ponds
- Construct surface water diversion system
- Slope stabilization, as necessary
- Material re-location
- Construct cap system
- Construct passive treatment systems
- Collect and treat runoff from TP-3 with passive treatment
- Collect and treat seepage from TP-1 with passive treatment

Substantial data gathering, testing, and engineering evaluation will be performed to develop a final design for Alternative 2C. Geotechnical data and evaluations will be used to determine the final surface and slope grades. Pilot testing and chemical analysis will support the design of the passive treatment systems. Hydraulic flow information about the tailings will help to better predict the impact of the cover system on the seeps of TP-1.

Each of the major components of Alternative 2C is described further below.

Material Relocation (Tailings and Waste Rock)

A portion of TP-2 that is currently across Copperas Brook (east side of the brook) from the main area of TP-2 would be excavated and hauled to TP-1. This “stranded“ tailings material resulted from massive erosion of the tailings pile along the former concrete decant pipe system below TP-2. Tailings materials from TP-2 would be used to fill low-lying portions of TP-1 and help achieve the design grade requirements for the final cap. A portion of TP-3 may also be removed and consolidated into TP-1, depending upon the final decision regarding TP-3. The exposed areas of TP-3 would be restored to promote vegetation or stabilized with rip-rap.

Grading and Slope Stabilization

The top surfaces of TP-1 and TP-2 would be regraded to an acceptable slope angle. The design will seek to optimize surface water run-off while minimizing the need for additional soil volume or exposure of the unoxidized tailings. The current slope angle is approximately 1%, from west to east and from north to south. Drainage from the surface of TP-1 would be diverted to the clean-water perimeter diversion channel. The oxide cap covering TP-1 would be retained as much as possible. The slope along the edge of TP-1 is very steep may require regrading, based on the final cover design. Stability and infiltration evaluations will be performed during design to determine if a steeper slope along the edge of TP-1 will meet the slope stability performance criteria for the proposed cover system. A steeper slope would better preserve the historic profile, reduce truck traffic, and minimize the exposure of unoxidized tailings. All of these issues will be finalized during the design.

Geomembrane Cap

A geomembrane-based cap will be installed over TP-1 and TP-2 under Alternative 2C to minimize water and oxygen infiltration into the tailings. Figure 3-2 provides a cross-sectional view of the proposed cap. The major components of the cap are described below:

Soil layer: This layer provides support for the vegetative cover, protects the barrier layers, and allows for the retention and use of water by vegetation. It will include approximately 6 inches of topsoil and 12 inches of additional soil material. The exact amount of soil will be determined during the design. EPA will try to minimize the thickness of this layer to reduce truck traffic. Alternative cover materials, such as stone, will also be evaluated during design.

Drainage layer: This layer allows for the drainage of water that flows through the soil layer and cannot flow past the barrier layer. A geosynthetic (engineered) drainage layer provides a conduit to carry water off the barrier layer without allowing the water to pond on top of the barrier layer.

Barrier layer: This layer prevent water from flowing into the tailings. The top barrier will be a geomembrane. During design, the need for a second barrier layer will be evaluated. If determined necessary, the second barrier layer would be a geosynthetic clay liner. The design will also evaluate the need for a barrier layer on the steep slopes. If design studies indicate that an acceptable degree of erosion stabilization and infiltration reduction can be achieved, an alternative cover configuration will be considered for the slopes of TP-1 and TP-2. The cover system will have a final grade to promote drainage off the cover and prevent ponding on the primary barrier layer.

Surface Water Diversion

A diversion channel would be constructed on each side of TP-1 and TP-2 to collect the surface water from the capping system and from the rest of the watershed. Since surface water runoff would never contact tailings material under this scenario, all runoff (except that associated with ground water seeps at the TP-1 toe drain) can be diverted around the base of the capped tailings into the Copperas Brook stream channel. The diversion channels would be constructed to a sufficient depth to collect shallow ground water.

The ground water would be intercepted at the margins of the tailings pile and diverted to Copperas Brook. One side of the channel may be lined with geomembrane or other suitable material to limit infiltration into the tailings. Throughout most of the year, the channeled flow through the diversion system would be relatively low. The channels must be designed, however, to handle the flow of a 100-year storm event, assuming minimal infiltration.

Passive Treatment Systems

Passive treatment systems for all Alternatives are described in Section 3.3.2.1. As part of the capping and containment strategy in Alternative 2C, a toe-drain system would be constructed to collect all discharges of ground water from the base of TP-1. Once the cap and diversion channels are in place, the tailings pile would begin to de-water, but only to a certain point. Ground water influx into the base of the tailings would continue. The design will include studies to determine the groundwater contribution to the post-cap flow. Assuming the perimeter diversion channels are successful at intercepting shallow ground water flow, the amount of recharge from the base is likely to be minimal. Currently, a series of five to six significant seeps can be observed during all seasons at the base of the TP-1 north slope. The rate of discharge varies to a small extent (compared to surface water flow) on a seasonal basis. Mid-winter flows are very similar to summer flow rates. Further reductions in seasonal variability are likely, following completion of the Alternative 2C cap and diversion scenario, since the primary contributions to seep flow (surface and shallow lateral ground water infiltration) would be eliminated. For preliminary costing purposes, we have assumed that the long-term flow rate of the combined seeps following cap construction is on the order of five to ten gpm. The current calculated flow at the toe of TP-1 is on the order of 110 gpm. The seasonal variability in deeper ground water flow in the Copperas Brook watershed, while uncertain at this point, is likely minimal (with the exception of the spring melt).

The components of a passive treatment system considered for possible application at TP-1 include an ALD, a water holding/retention basin(s), a pair of SAPS in parallel or a SRB(s), and an aerobic wetland. The water flowing from the base of the tailings has high concentrations of dissolved ferrous iron and aluminum. Effective treatment through the use of an ALD plus one or two SAPS ponds or SRBs would increase the alkalinity of seep water, remove the iron and aluminum, remove sulfate and remove other metals such as copper and zinc. Finally, the treated water would be discharged to an aerobic wetland, designed as a polishing step to ensure that metals concentrations fall below the established treatment objectives and return oxygen to the water prior to discharge to Copperas Brook. Since storm events under this Alternative would largely discharge clean runoff water around TP-1, there is likely to be little to no effect on flow rates experienced in the toe drain system itself. The toe drain system, ALD, catchment basin(s), buffering system, and SAPS/SRBs would be constructed such that storm water does not mix with and overwhelm seepage water that must be treated. The wetland component of the treatment system would be subject to inundation from large storm events. All drainage systems would be constructed to minimize the effect of these events on wetland functionality.

A separate passive treatment system will be installed for TP-3 (as described in Section 3.3.2.1). The components considered for possible application to TP-3 include: a water holding/retention basin, SPAD, settling basin for SPAD sludge, drying basin for SPAD sludge, a SRB, and an aerobic wetland with algal mats. Accomplishing the treatment of AMD for TP-3 through a passive or semi-passive system appears within reach of existing technologies. The treatment system for TP-3 must meet VTWQS on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for copper. EPA expects that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. Data from pilot-scale treatability studies will be used to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal. Nevertheless, it seems quite likely that a passive or semi-passive treatment system can be designed for the TP-3 contamination that has a reasonable probability of success.

Detailed analysis of potential passive treatment systems for TP-1 and TP-3 will be performed as part of the design process. Modular systems are envisioned, where additional treatment units can be added to account for periodic higher flow rates. Settling ponds and the aerobic wetland system would be designed with excess capacity to allow for substantially greater flows.

Winter conditions in Vermont will impact the functionality of wetland treatment systems to some extent, especially during deep-freeze periods with little to no insulation from snow cover (typical November and December conditions). Recent studies by Montana Tech (K. Burgher, 2001, Personal Communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged. These issues will be addressed in detail during the design.

Post-Removal Site Control (PRSC)

PRSC represents those activities that must be performed to maintain the effectiveness of the cleanup alternative. The EPA Removal Authority cannot be used to perform or finance PRSC. It is assumed that the State of Vermont will be responsible for the PRSC at the Site.

For Alternative 2C, PRSC includes the following activities:

- Sampling and analysis of the effluent from the passive treatment systems as necessary to demonstrate compliance with the discharge criteria
- Inspection of cap/cover and passive systems (monthly, then quarterly)
- Periodic sediment removal and repair of diversion channels (as necessary, assumed one-year cycle)
- Periodic cleanout of water retention/holding basin(s) (as necessary, assumed one-year cycle)
- Re-charging of limestone (or equivalent) and organic compost in passive system for treatment of seeps (assumed 10-year cycle for all TP-3 Options and 15 years for TP-1) and disposal of metal sludge from passive system components
- Periodic cleanout/replanting/repair of wetland (15-year cycle)

Cost

The major costs for Alternative 2C are associated with regrading, capping, building diversion channels, seepage collection system, water holding ponds, and passive treatment systems. While the regrading costs are considerably less than in Alternative 2B, factors affecting the cost of Alternative 2C include the following:

- Location of a borrow source for the soil/cover layer (increased costs with increased haul distance
- Cost of low permeability liner and drainage geocomposite
- Frequency of passive treatment system cleanout

The construction and capital cost for this alternative is estimated to range from $12.9 million to $15.5 million depending upon the amount of TP-3 to be removed. See Table 3-3 for a more detail regarding cost.

Annual PRSC for routine maintenance activities of the cap and drainage structures and the TP-1 passive treatment system is $90,000 per year. The annual PRSC for TP-3 varies with the amount of preservation. For complete removal of TP-3 some costs would be incurred to stabilize erosion while the area becomes vegetated. For the preservation of TP-3, the annual maintenance costs are in the range of $153,000 for preservation Options 2 and 3 to $400,000 for the complete preservation of TP-3 (see Table 3-4 for a more detailed presentation of the costs). Minor additional costs are likely for the inspection and repair of the high-angle stabilized slopes on TP-1 and TP-2. PRSC for the TP-1 passive treatment system is likely to decrease substantially following cap construction, due to the reduced flow seeping from the source material.

3.3.5 Alternative 3B

3.3.5.1 Objectives

Alternative 3B is designed to stabilize tailings piles, limit erosion and transport of tailings material, and reduce surface water infiltration into tailings and surface water runoff, thus reducing the formation of AMD. This would be accomplished through construction of an evapotranspiration (ET) soil cover over TP-1 and TP-2.

3.3.5.2 Detailed Description of Alternative

Treatment Components

Alternative 3B has the same objectives as Alternative 2C, but uses an ET cover of sufficient thickness for evaporation and plant transpiration to reduce rain water infiltration, instead of a multi-layer cap system. Analyses indicate that a minimum cover thickness of approximately 42 inches is needed to achieve the ET performance requirements for Vermont. This consists of 36 inches of common borrow material with a six-inch topsoil cover, capable of supporting a diverse plant population, including trees. See Figure 3-4 for a plan view of this alternative. Alternative 3B consists of the following activities and components:

- Pre-design investigations including geotechnical studies and pilot testing of passive treatment systems
- Engineering design
- Mobilization and site preparation
- Construct holding ponds
- Construct surface water diversion system
- Slope stabilization, as necessary
- Material re-location
- Construct cap system
- Construct passive treatment systems
- Collect and treat runoff from TP-3 with passive treatment
- Collect and treat seepage from TP-1 with passive treatment

Depending on funding, these activities may be phased, as described in Section 2.0 of this EE/CA. Substantial data gathering, testing, and engineering evaluation will be performed to develop a final design for Alternative 3B. Geotechnical data and evaluations will be used to determine the final surface and slope grades. Pilot testing and chemical analysis will support the design of the passive treatment systems. Hydraulic flow information about the tailings will help to better predict the impact of the cover system on the seeps of TP-1. Each of the major components of Alternative 3B is described further below.

Material Relocation (Tailings and Waste Rock)

A portion of TP-2 that is currently situated across Copperas Brook (to the east) from the main area of TP-2 would be excavated and hauled to TP-1. Tailings materials from this portion of TP-2 would be used to fill low-lying portions of TP-1 and help achieve the design grade requirements for the final cap. A portion of TP-3 may also be removed and consolidated into TP-1, depending upon the final decision regarding TP-3. The exposed areas of TP-3 would be restored to promote vegetation or stabilized with rip- rap.

Grading and Slope Stabilization

The top surfaces of TP-1 and TP-2 would be regraded to an acceptable slope angle. The design will seek to optimize surface water run-off while minimizing the need for additional soil volume or exposure of the unoxidized tailings. The current slope angle is approximately 1%, from west to east and from north to south. Drainage from the surface of TP-1 would be diverted to the clean-water perimeter diversion channel. The oxide cap covering TP-1 would be retained as much as possible. The slope along the edge of TP-1 may require regrading, based on the final cover design. Stability and infiltration evaluations will be performed during design to determine if a steeper slope along the edge of TP-1 will meet the slope stability performance criteria for the proposed cover system. A steeper slope would better preserve the historic profile, reduce truck traffic, and minimize the exposure of unoxidized tailings. All of these issues will be finalized during the design.

Evapo-Transpiration Cover

The cover system will have a final grade to promote drainage off the cover and prevent ponding on the primary barrier layer. This alternative takes advantage of soil cover technologies that have been demonstrated to be effective under certain conditions. Soil covers are effective, low-cost alternatives for situations that allow water and oxygen infiltration to the materials below the cover. They are especially effective in arid and semi-arid climates where evapotranspiration removes much of the water that falls on the surface of the covered materials. The soil cover is estimated to be 42 inches thick. To comply with VTSWMR, the bottom 18 inches of the cover would be required to have a permeability less than 1×10^{-5} cm./sec.

Surface Water Diversion

A diversion channel would be constructed on each side of TP-1 and TP-2 to collect the surface water from the soil cover and from the rest of the watershed. All runoff (except that associated with ground water seeps at the TP-1 toe drain) can be diverted around the base of the capped tailings into the Copperas Brook stream channel. The diversion channels would be constructed to a sufficient depth to collect shallow ground water. The ground water would be intercepted at the margins of the tailings pile and diverted to Copperas Brook. One side of the channel may be lined with geomembrane or other suitable material to limit infiltration into the tailings . Throughout most of the year, the channeled flow through the diversion system would be relatively low. The channels must be designed, however, to handle the flow of a 100-year storm event, assuming minimal infiltration.

Passive Treatment Systems

Passive treatment systems for all Alternatives are described in Section 3.3.2.1. As part of the soil cover strategy in Alternative 3B, a toe-drain system would be constructed to collect all discharges of ground water from the base of TP-1. Once the cover and diversion channels are in place, the tailings pile would begin to de-water, but only to a certain point. Infiltration and ground water influx into the base of the tailings would continue at a reduced rate. The design will include studies to determine the groundwater contribution to the post-cover flow. Assuming the perimeter diversion channels are successful at intercepting shallow ground water flow, the amount of recharge from the base is likely to be minimal. Currently, a series of five to six significant seeps can be observed during all seasons at the base of the TP-1 north slope. The rate of discharge varies to a small extent (compared to surface water flow) on a seasonal basis. Mid-winter flows are very similar to summer flow rates. Further reductions in seasonal variability are likely, following completion of the Alternative 3B cover and diversion scenario, since the primary contributions to seep flow (surface and shallow lateral ground water infiltration) would be reduced. For preliminary costing purposes, we have assumed that the long-term flow rate of the combined seeps from infiltration, following cover construction, is on the order of 15 gpm. The current calculated flow at the toe of TP-1 is on the order of 110 gpm. The seasonal variability in deeper ground water flow in the Copperas Brook watershed, while uncertain at this point, is likely minimal (with the exception of the spring melt).

The components of a passive treatment system considered for possible application at TP-1 include an ALD, a water holding/retention basin(s), a pair of SAPS in parallel or a SRB(s), and an aerobic wetland. The water flowing from the base of the tailings has high concentrations of dissolved ferrous iron and aluminum. Effective treatment through the use of an ALD plus one or two SAPS ponds or SRBs would increase the alkalinity of seep water, remove the iron and aluminum, remove sulfate and remove other metals such as copper and zinc. Finally, the treated water would be discharged to an aerobic wetland, designed as a polishing step to ensure that metals concentrations fall below the established treatment objectives and return oxygen to the water prior to discharge to Copperas Brook. Since storm events under this Alternative would largely discharge clean runoff water around TP-1, there is likely to be little to no effect on flow rates experienced in the toe drain system itself. The toe drain system, ALD, catchment basin(s), buffering system, and SAPS/SRBs would be constructed such that storm water does not mix with and overwhelm seepage water that must be treated. The wetland component of the treatment system would be subject to inundation from large storm events. All drainage systems would be constructed to minimize the effect of these events on wetland functionality.

A separate passive treatment system will be installed for TP-3 (as described in Section 3.3.2.1). The components considered for possible application to TP-3 include: a water holding/retention basin, SPAD, settling basin for SPAD sludge, drying basin for SPAD sludge, a SRB, and an aerobic wetland with algal mats. Accomplishing the treatment of AMD for TP-3 through a passive or semi-passive system appears within reach of existing technologies. The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for copper. EPA expects that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. Data from pilot-scale treatability studies will be used to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal. Nevertheless, it seems quite likely that a passive or semi-passive treatment system can be designed for the TP-3 contamination that has a reasonable probability of success.

Detailed analysis of potential passive treatment systems for TP-1 and TP-3 will be performed as part of the design process. Modular systems are envisioned, where additional treatment units can be added to account for periodic higher flow rates. Settling ponds and the aerobic wetland system would be designed with excess capacity to allow for substantially greater flows. Winter conditions in Vermont will impact the functionality of wetland treatment systems to some extent, especially during deep-freeze periods with little to no insulation from snow cover (typical November and December conditions). Recent studies by Montana Tech (K. Burgher, 2001, Personal Communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged. These issues will be addressed in detail during the design.

Post-Removal Site Control (PRSC)

PRSC represents those activities that must be performed to maintain the effectiveness of the cleanup alternative. The EPA Removal Authority cannot be used to perform or finance PRSC. It is assumed that the State of Vermont will be responsible for the PRSC at the Site.

For Alternative 3B, PRSC includes the following activities:

- Sampling and analysis of the effluent from the passive treatment systems as necessary to demonstrate compliance with the discharge criteria
- Inspection of cap/cover and passive systems (monthly, then quarterly)
- Periodic sediment removal and repair of diversion channels (as necessary, assumed one-year cycle)
- Periodic cleanout of water retention/holding basin(s) (as necessary, assumed one-year cycle)
- Re-charging of limestone (or equivalent) and organic compost in passive system for treatment of seeps (assumed 10 year cycle for all TP-3 Options and 15 years for TP-1) and disposal of metal sludge from passive system components
- Periodic cleanout/replanting/repair of wetland (15 year cycle)

Cost

The costs for Alternative 3B are associated with regrading, soil cover, building diversion channels, seepage collection system, water holding ponds and passive treatment system, slope stabilization, and PRSC. The critical factors associated with the cost of Alternative 3B include the following:

- Location of a borrow source for the soil/cover layer (increased costs with increased haul distance)
- Volumes of earth to be moved and regraded
- Management and control of exposed fresh sulfides during construction
- Frequency of passive system cleanout

The construction and capital cost for this alternative is estimated to range from $12.3 million to $14.9 million, depending upon the amount of TP-3 to be removed (see Table 3-3 for more details regarding cost). Annual PRSC for routine maintenance activities of the cover and drainage structures and the TP-1 passive treatment system is $110,000 per year (see Table 3-4). The annual PRSC for TP-3 varies with the amount of preservation. For complete removal of TP-3 some costs would be incurred to stabilize erosion while the area becomes vegetated. For the preservation of TP-3, the annual maintenance costs are in the range of $153,000 for preservation Options 2 and 3 to $400,000 for the complete preservation of TP-3. PRSC for Alternative 3B will be slightly higher than the options presented under Alternative 2C, due to the need to operate passive treatment systems at a higher flow rate.

3.3.6 Alternative 3C

3.3.6.1 Objectives

Alternative 3C is designed to stabilize tailings piles, limit erosion and transport of tailings material, reduce surface water infiltration into tailings and surface water runoff, thus reducing the formation of AMD. This would be accomplished by the construction of a minimal (six-inch) soil cover over TP-1 and TP-2.

3.3.6.2 Detailed Description of Alternative Treatment Components

Alternative 3C has the same objectives as Alternative 3B but seeks to minimize the soil cover to achieve the necessary level of protection. A six-inch topsoil cover over all of TP-1 and TP-2 is considered for this alternative. See Figure 3-5 for a plan view of this Alternative. This alternative consists of the following components:

- Pre-design investigations including geotechnical studies and pilot testing of passive treatment systems
- Engineering design
- Mobilization and site preparation
- Construct holding ponds

- Construct surface water diversion system
- Slope stabilization, as necessary
- Material re-location
- Construct cap system
- Construct passive treatment systems
- Collect and treat runoff from TP-3 with passive treatment
- Collect and treat seepage from TP-1 with passive treatment

Substantial data gathering, testing, and engineering evaluation will be performed to develop a final design for Alternative 3C. Geotechnical data and evaluations will be used to determine the final surface and slope grades. Pilot testing and chemical analysis will support the design of the passive treatment systems. Hydraulic flow information about the tailings will help to better predict the impact of the soil cover system on the seeps of TP-1. Each of the major components of Alternative 3C is described further below.

Material Relocation (Tailings and Waste Rock)
A portion of TP-2 that is currently situated across Copperas Brook from the main area of TP-2 (to the east) would be excavated and hauled to TP-1. This tailings material would be used to fill low-lying portions of TP-1 and help achieve the design grade requirements for the final cap. A portion of TP-3 may also be removed and consolidated into TP-1 depending upon the final decision regarding TP-3. The exposed areas of TP-3 would be restored to promote vegetation or stabilized with rip rap.

Grading and Slope Stabilization
The top surfaces of TP-1 and TP-2 would be regraded to an acceptable slope angle. The design will seek to optimize surface water run-off while minimizing the need for additional soil volume or exposure of the unoxidized tailings. The current slope angle is approximately 1%, from west to east and from north to south. Drainage from the surface of TP-1 would be diverted to the clean-water perimeter diversion channel. The oxide cap covering TP-1 would be retained as much as possible. The slope along the edge of TP-1 is very steep and may require regrading based on the final cover design. Stability and infiltration evaluations will be performed during design to determine if a steeper slope along the edge of TP-1 will meet the slope stability performance criteria for the proposed cover system. A steeper slope would better preserve the historic profile, reduce truck traffic, and minimize the exposure of unoxidized tailings. All of these issues will be finalized during the design.

Soil Cover
The 6-inch soil cover will have a final grade to promote drainage off the cover and prevent ponding. There is no infiltration barrier or internal drainage components for this cover.

Surface Water Diversion

A diversion channel would be constructed on each side of TP-1 and TP-2 to collect the surface water from the soil cover and from the rest of the watershed. The diversion channels would be constructed to a sufficient depth to collect shallow ground water. The ground water would be intercepted at the margins of the tailings pile and diverted to Copperas Brook. One side of the channel may be lined with geomembrane or other suitable material to limit infiltration into the tailings. Throughout most of the year, the channeled flow through the diversion system would be relatively low. The channels must be designed, however, to handle the flow of a 100-year storm event, assuming minimal infiltration.

Passive Treatment Systems

Passive treatment systems for all Alternatives are described in Section 3.3.2.1. As part of the cover strategy in Alternative 3C, a toe-drain system would be constructed to collect all discharges of ground water from the base of the combined tailings pile. Once the cap and diversion channels are in place, the tailings pile would begin to de-water, but only to a certain point. Infiltration and ground water influx into the base of the tailings would continue. The design will include studies to determine the groundwater contribution to the post-cover flow. Assuming the perimeter diversion channels are successful at intercepting shallow ground water flow, the amount of recharge from the base is likely to be minimal. Currently, a series of five to six significant seeps can be observed during all seasons at the base of the TP-1 north slope. The rate of discharge varies to a small extent (compared to surface water flow) on a seasonal basis. Mid-winter flows are very similar to summer flow rates. For preliminary costing purposes, we have assumed that the long-term flow rate of the combined seeps following cover construction is on the order of 60 gpm. The current calculated flow at the toe of TP-1 is on the order of 110 gpm. The seasonal variability in deeper ground water flow in the Copperas Brook watershed, while uncertain at this point, is likely minimal (with the exception of the spring melt).

The components of a passive treatment system considered for possible application at TP-1 include an ALD, a water holding/retention basin(s), a pair of SAPS in parallel or a SRB(s), and an aerobic wetland. The water flowing from the base of the tailings has high concentrations of dissolved ferrous iron and aluminum. Effective treatment through the use of an ALD plus one or two SAPS ponds or SRBs would increase the alkalinity of seep water, remove the iron and aluminum, remove sulfate and remove other metals such as copper and zinc. Finally, the treated water would be discharged to an aerobic wetland, designed as a polishing step to ensure that metals concentrations fall below the established treatment objectives and return oxygen to the water prior to discharge to Copperas Brook. Since storm events under this Alternative would largely discharge clean runoff water around TP-1, there is likely to be little to no effect on flow rates experienced in the toe drain system itself. The toe drain system, ALD, catchment basin(s), buffering system, and SAPS/SRBs would be constructed such that storm water does not mix with and overwhelm seepage water that must be treated. The wetland component of the treatment system would be subject to inundation from large storm events. All drainage systems would be constructed to minimize the effect of these events on wetland functionality.

A separate passive treatment system will be installed for TP-3 (as described in Section 3.3.2.1). The components considered for possible application to TP-3 include: a water holding/retention basin, SPAD, settling basin for SPAD sludge, drying basin for SPAD sludge, a SRB, and an aerobic wetland with algal mats. Accomplishing the treatment of AMD for TP-3 through a passive or semi-passive system appears within reach of existing technologies. The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for. EPA expects that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. Data from pilot-scale treatability studies will be used to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal. Nevertheless, it seems quite likely that a passive or semi-passive treatment system can be designed for the TP-3 contamination that has a reasonable probability of success.

Detailed analysis of potential passive treatment systems for TP-1 and TP-3 will be performed as part of the design process. Modular systems are envisioned, where additional treatment units can be added to account for periodic higher flow rates. Settling ponds and the aerobic wetland system would be designed with excess capacity to allow for substantially greater flows.

Winter conditions in Vermont will impact the functionality of wetland treatment systems to some extent, especially during deep-freeze periods with little to no insulation from snow cover (typical November and December conditions). Recent studies by Montana Tech (K. Burgher, 2001, Personal Communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged. These issues will be addressed in detail during the design.

Post-Removal Site Control (PRSC)

PRSC represents those activities that must be performed to maintain the effectiveness of the cleanup alternative. The EPA removal authority cannot be used to perform or finance PRSC. It is assumed that the State of Vermont will be responsible for the PRSC at the Site.

For Alternative 3C, PRSC includes the following activities:

- Sampling and analysis of the effluent from the passive treatment systems as necessary to demonstrate compliance with the discharge criteria
- Inspection of soil cover and passive systems (monthly, then quarterly)
- Periodic sediment removal and repair of diversion channels (as necessary, assumed one-year cycle)
- Periodic cleanout of water retention/holding basin(s) (as necessary, assumed one-year cycle)
- Re-charging of limestone (or equivalent) and organic compost in passive system for treatment of seeps (assumed 10-year cycle for all TP-3 Options and 15 years for TP-1)) and disposal of metal sludge from passive system components
- Periodic cleanout/replanting/repair of wetland (15-year cycle)

Cost

The costs for Alternative 3C are associated with regrading, soil cover, building diversion channels, seepage collection system, water holding ponds and passive treatment system, slope stabilization, and PRSC. The critical factors associated with the cost of Alternative 3C include the following:

- Location of a borrow source for the soil/cover layer (increased costs with increased haul distance)
- Volumes of earth to be moved and regraded
- Management and control of exposed fresh sulfides during construction
- Frequency of passive system cleanout
- Frequency of repair of the minimal soil cover to prevent exposure of tailings

The construction and capital cost for this alternative is estimated to range from $9.4 million to $12.0 million, depending upon the amount of TP-3 to be removed. See Table 3-3 for more details regarding cost.

Annual PRSC for routine maintenance activities of the cap and drainage structures and the TP-1 passive treatment system is $132,000 per year. The annual PRSC for TP-3 varies with the amount of preservation. For complete removal of TP-3, some costs would be incurred to stabilize erosion while the area becomes vegetated. For the preservation of TP-3, the annual maintenance costs are in the range of $153,000 for preservation Options 2 and 3 to $400,000 for the complete preservation of TP-3. PRSC for Alternative 3C will be higher than the options presented under Alternative 2C and 3B, due to the need to operate passive treatment systems at a higher flow rate. See Table 3-4 for a more detailed presentation of the costs.

3.3.7 Alternative 3D

3.3.7.1 Objectives

Alternative 3D is designed to stabilize tailings piles, limit erosion and transport of tailings material, reduce surface water infiltration into tailings and surface water runoff, thus reducing the formation of AMD.

3.3.7.2 Detailed Description of Alternative

Treatment Components

Alternative 3D has the same objectives as Alternatives 3B and 3C but incorporates an induced chemical hardpan formation with a soil cover and drainage layer to minimize potential infiltration and support a grass covered surface. See Figure 3-6 for a plan view of this alternative. This alternative consists of the following components:

- Pre-design investigations including geotechnical studies and pilot testing of passive treatment systems
- Engineering design
- Mobilization and site preparation
- Construct holding ponds
- Construct surface water diversion system
- Slope stabilization, as necessary
- Material re-location
- Construct cover/cap system
- Construct passive treatment systems
- Collect and treat runoff from TP-3 with passive treatment
- Collect and treat seepage from TP-1 with passive treatment

Substantial data gathering, testing, and engineering evaluation will be performed to develop a final design for Alternative 3D. Geotechnical data and evaluations will be used to determine the final surface and slope grades. Pilot testing and chemical analysis will support the design of the passive treatment systems and hardpan. Hydraulic flow information about the tailings will help to better predict the impact of the cover system on the seeps of TP-1.

Each of the major components of Alternative 3D is described further below.

Material Relocation (Tailings and Waste Rock). A portion of TP-2 that is currently situated across Copperas Brook from the main area of TP-2 (to the east) would be excavated and hauled to TP-1. That tailings material would be used to fill low-lying portions of TP-1 and help achieve the design grade requirements for the final cover. A portion of TP-3 may also be removed and consolidated into TP-1, depending upon the final decision regarding TP-3. The exposed areas of TP-3 would be restored to promote vegetation or stabilized with rip rap.

Grading and Slope Stabilization

The top surfaces of TP-1 and TP-2 would be regraded to an acceptable slope angle. The design will seek to optimize surface water run-off while minimizing the need for additional soil volume or exposure of the unoxidized tailings. The current slope angle is approximately 1%, from west to east and from north to south. Drainage from the surface of TP-1 would be diverted to the clean-water perimeter diversion channel. The oxide cap covering TP-1 would be retained as much as possible. The slope along the edge of TP-1 is very steep and may require regrading, based on the final cover design. Stability and infiltration evaluations will be performed during design to determine if a steeper slope along the edge of TP-1 will meet the slope stability performance criteria for the proposed cover system. A steeper slope would better preserve the historic profile, reduce truck traffic, and minimize the exposure of unoxidized tailings. All of these issues will be finalized during the design.

Soil Cover and Chemical Cap

The soil cover and chemical cap system will have a final grade to promote drainage off the cover and prevent ponding. To install the crushed limestone for hardpan formation, as well as the soil cover, the existing tailings piles need to be regraded. Three to six inches of crushed limestone, coupled with eighteen inches of common borrow, overlain by six inches of topsoil would be placed over the areas to be reseeded. A drainage layer would be placed over the crushed limestone. The limestone will placed directly on top of the tailings. Induced chemical hardpan capping is a technology that is currently being developed specifically for AMD generated by sulfide-rich tailings and waste rock. Hardpan capping relies on chemical reactions between sulfide waste rock and lime/limestone applied to a tailing pile surface to create a hardpan layer or cap. The advantage of a chemical hardpan is that it would, in theory, require relatively low maintenance, as the cap is “self-healing,” (i.e., when holes or cracks form in the cap and water enters, more capping material is formed by the chemical reaction)(Chermak and Runnells, 1996). However, there is a possibility that additional applications of limestone would be required to maintain the hardpan. Also, the material is very brittle and would limit site re-use.

Surface Water Diversion

A diversion channel would be constructed on each side of TP-1 and TP-2 to collect the surface water from the cover system and from the rest of the watershed. The diversion channels would be constructed to a sufficient depth to collect shallow ground water. The ground water would be intercepted at the margins of the tailings pile and diverted to Copperas Brook. One side of the channel may be lined with geomembrane or other suitable material to limit infiltration into the tailings. Throughout most of the year, the channeled flow through the diversion system would be relatively low. The channels must be designed, however, to handle the flow of a 100-year storm event, assuming minimal infiltration.

Passive Treatment Systems

Passive treatment systems for all Alternatives are described in Section 3.3.2.1. As part of the cover strategy in Alternative 3D, a toe-drain system would be constructed to collect all discharges of ground water from the base of the combined tailings pile. Once the cap and diversion channels are in place, the tailings pile would begin to de-water, but only to a certain point. Infiltration and ground water influx into the base of the tailings would continue. The Design will include studies to determine the groundwater contribution to the post-cover flow. Assuming the perimeter diversion channels are successful at intercepting shallow ground water flow, the amount of recharge from the base is likely to be minimal. Currently, a series of five to six significant seeps can be observed during all seasons at the base of the TP-1 north slope. The rate of discharge varies to a small extent (compared to surface water flow) on a seasonal basis. Mid-winter flows are very similar to summer flow rates. For preliminary costing purposes, we have assumed that the long-term flow rate of the combined seeps following cover construction is on the order of 8 gpm. The current calculated flow at the toe of TP-1 is on the order of 110 gpm.

The seasonal variability in deeper ground water flow in the Copperas Brook watershed, while uncertain at this point, is likely minimal (with the exception of the spring melt).

The components of a passive treatment system considered for possible application at TP-1 include an ALD, a water holding/retention basin(s), a pair of SAPS in parallel or a SRB(s), and an aerobic wetland. The water flowing from the base of the tailings has high concentrations of dissolved ferrous iron and aluminum. Effective treatment through the use of an ALD plus one or two SAPS ponds or SRBs would increase the alkalinity of seep water, remove the iron and aluminum, remove sulfate and remove other metals such as copper and zinc. Finally, the treated water would be discharged to an aerobic wetland, designed as a polishing step to ensure that metals concentrations fall below the established treatment objectives and return oxygen to the water prior to discharge to Copperas Brook. Since storm events under this Alternative would largely discharge clean runoff water around TP-1, there is likely to be little to no effect on flow rates experienced in the toe drain system itself. The toe drain system, ALD, catchment basin(s), buffering system, and SAPS/SRBs would be constructed such that storm water does not mix with and overwhelm seepage water that must be treated. The wetland component of the treatment system would be subject to inundation from large storm events. All drainage systems would be constructed to minimize the effect of these events on wetland functionality.

A separate passive treatment system will be installed for TP-3 (as described in Section 3.3.2.1). The components considered for possible application to TP-3 include: a water holding/retention basin, SPAD, settling basin for SPAD sludge, drying basin for SPAD sludge, a SRB, and an aerobic wetland with algal mats. Accomplishing the treatment of AMD for TP-3 through a passive or semi-passive system appears within reach of existing technologies. The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for copper. EPA expects that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. Data from pilot-scale treatability studies will be used to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal. Nevertheless, it seems quite likely that a passive or semi-passive treatment system can be designed for the TP-3 contamination that has a reasonable probability of success.

Detailed analysis of potential passive treatment systems for TP-1 and TP-3 will be performed as part of the design process. Modular systems are envisioned, where additional treatment units can be added to account for periodic higher flow rates. Settling ponds and the aerobic wetland system would be designed with excess capacity to allow for substantially greater flows.

Winter conditions in Vermont will impact the functionality of wetland treatment systems to some extent, especially during deep-freeze periods with little to no insulation from snow cover (typical November and December conditions). Recent studies by Montana Tech (K. Burgher, 2001, Personal Communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged. These issues will be addressed in detail during the design.

Post-Removal Site Control (PRSC)

PRSC represents those activities that must be performed to maintain the effectiveness of the cleanup alternative. The EPA removal authority cannot be used to perform or finance PRSC. It is assumed that the State of Vermont will be responsible for the PRSC at the Site.

For Alternative 3D, PRSC includes the following activities:

- Sampling and analysis of the effluent from the passive treatment systems as necessary to demonstrate compliance with the discharge criteria
- Inspection of cap/cover and passive systems (monthly, then quarterly)
- Periodic sediment removal and repair of diversion channels (as necessary, assumed one-year cycle)
- Periodic cleanout of water retention/holding basin(s) (as necessary, assumed one-year cycle)

- Re-charging of limestone (or equivalent) and organic compost in passive system for treatment of seeps (assumed 10-year cycle for all TP-3 Options and 15 years for TP-1) and disposal of metal sludge from passive system components
- Periodic cleanout/replanting/repair of wetland (15-year cycle)

Cost

The costs for Alternative 3D are associated with regrading, limestone and soil cover, building diversion channels, seepage collection system, water holding ponds and passive treatment system, slope stabilization, and PRSC. The critical factors associated with the cost of Alternative 3D include the following:

- Location of a borrow source for the soil/cover layer (increased costs with increased haul distance
- Volumes of earth to be moved and regraded
- Management and control of exposed fresh sulfides during construction
- Frequency of passive system cleanout
- Effectiveness of the induced hardpan

The construction and capital cost for this alternative is estimated to range from $12.0 million to $14.6 million depending upon the amount of TP-3 to be removed. See Table 3-3 for a more detail regarding cost.

Annual PRSC for routine maintenance activities of the cap and drainage structures and the TP-1 passive treatment system is $90,000 per year. The annual PRSC for TP-3 varies with the amount of preservation. For complete removal of TP-3 some costs would be incurred to stabilize erosion while the area becomes vegetated. For the preservation of TP-3, the annual maintenance costs range from $153,000 for preservation Options 2 and 3 to $400,000 for the complete preservation of TP-3. See Table 3-4 for a more detailed presentation of the costs.

PRSC includes periodic maintenance of the passive treatment system. PRSC for Alternative 3D will be slightly higher than the options presented under Alternative 2C, due to the need to operate passive treatment systems at a slightly higher flow rate.

4.0 Analysis of Removal Action Alternatives

Section 4.0 presents an analysis of the Removal Action Alternatives. The alternatives (see Table 4-1) are evaluated on the basis of effectiveness, implementability, and cost, pursuant to EPA guidance on development of an EE/CA. Each alternative considered in this EE/CA exceeds the $2 million statutory limit; therefore, alternatives are further evaluated to determine the consistency with future remedial actions to be taken at the Site.

The Removal Action Alternatives described in this section are designed to address the tailings and mine waste piles (TP-1, TP-2, and TP-3) located in the Copperas Brook watershed.

While several additional known and potential contaminant source areas are present at the mine Site, the NTCRA phase is focused on addressing contamination associated with the tailings alone. Other source areas will be addressed under the future Remedial Program, following completion of the RI/FS. Planning for the RI/FS will take place over the coming months and implementation will begin in late 2001 or in early 2002.

4.1 Approach

Each alternative is evaluated on the basis of effectiveness, implementability, and cost, as set forth in the NCP and EPA guidance on conducting EE/CAs.

4.1.1 Effectiveness

Effectiveness refers to the ability of an alternative to meet the removal action objectives. The effectiveness of each alternative is evaluated in accordance with the following criteria:

- Overall protection of human health and the environment
- Compliance with ARARs and other criteria, advisories, and guidance
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness

4.1.2 Implementability

Implementability addresses the technical and administrative feasibility of implementing an alternative and availability of various required services and materials. Implementability is evaluated in accordance with the following criteria:

- Technical feasibility

- Administrative feasibility
- Availability of services and materials
- State acceptance
- Community acceptance

4.1.3 Cost

A cost estimate is prepared for each alternative to help EPA and the State in the selection of a removal action. Each estimate contains the capital cost, (consisting of direct and indirect costs), and the Post-Removal Site Control (PRSC or operations and maintenance) costs.

Capital costs include those expenditures initially incurred to develop, design, and implement the removal alternative. Direct costs include expenditures for the equipment, labor, and materials necessary to prepare the site, regrade the tailings, stabilize the slopes, and construct the passive treatment systems. Indirect costs include additional costs for services that are not actually components of the alternatives, but that are required to complete the project implementation.

The PRSC costs include sampling and analysis of the effluent from the passive treatment systems, inspection and maintenance of cap/cover (including mowing) and passive systems, and periodic cleanout/repair of diversion channels and passive treatment systems.

4.2 Alternative 2B

4.2.1 Description (2B)

The objectives of Alternative 2B are to isolate the tailings material from interaction with water and oxygen, thereby eliminating (or significantly reducing) the generation of AMD (see Figure 3-2 for Alternative 2B conceptual drawing and Section 3.0 for a detailed description of Alternative 2B). To accomplish this primary objective, Alternative 2B relies on diversion of shallow groundwater and surface water around the tailings, limiting infiltration into the tailings through a low permeability cover system, and collection and treatment of the seeps of TP-1 and run-off from TP-3.

4.2.1.1 Overall Protection of Human Health and the Environment (2B)

Alternative 2B achieves overall protection of human health and the environment by the following:

TP-3

For TP-3, overall protection of human health and the environment is accomplished through the collection of the discharge (run-off and groundwater) from the waste rock and heap leach piles of TP-3 and subsequent treatment of this water in a treatment system. The passive treatment system will treat the collected water to meet VTWQS. The result will be a discharge to Copperas Brook and the WBOR that no longer has an adverse impact on these receiving waters. As TP-3 will remain exposed, ongoing erosion must be an accepted condition of long-term performance if the historical integrity of the tailings is to be preserved. Some exposure to site contaminants would occur as a result of long-term human contact and wind blown transport of the material within TP-3. The concentration of metals found in TP-3, are not above levels that would warrant measures to prevent exposure to this material. Further studies of TP-3 will be performed during design to confirm that the material in TP-3 does not represent a threat to human health. Any waste rock, or heap leach piles removed from TP-3 will be placed under the cover system for TP-1. Material placed under the cover system included in this Alternative (2B) would no longer be a source of AMD.

TP-1
For TP-1 (TP-2 is consolidated into TP-1 under this Alternative), overall protection of human health and the environment is accomplished through the covering of the exposed tailings, stabilization of the steep slopes, and reduction in the generation of AMD. A vegetated soil or rock cover over the tailings will effectively stabilize the tailings surface to prevent windblown transport of dust and minimize erosion. Stabilization of the TP-1 slopes would occur if design studies indicate a potential for failure of the tailings or cover system at the current slope configuration. The filling of the decant pipes will further improve the stability of TP-1. The cap and perimeter diversion ditch will effectively minimize the amount of water entering the TP-1 resulting in a dramatic reduction in AMD from TP-1. The estimated long-term ground water influx into the combined tailings will be on the order of five to ten gpm; so the seepage at the toe of the combined tailings pile will be on the order of five to ten gpm (possibly less). The seepage will be collected with a toe-drain system and treated using the passive treatment system. The effluent of the passive treatment is expected to meet the discharge criteria, which will be based upon VTWQS.

4.2.1.2 Compliance With ARARs and Other Criteria, Advisories, and Guidance (2B)
Table 4-2 identifies the ARARs that apply to Alternative 2B. Alternative 2B would comply with all federal and state location-, chemical-, and action-specific ARARs that apply to the Site. As part of the ARAR evaluation, EPA is specifically seeking public comment on the following:

Unavoidable Impacts to Wetlands and Floodplain:

> The Wetlands below TP-1, on the surface of TP-1, adjacent to the adit, and within the stream channel of Copperas Brook from TP-3 to the outlet of TP-1 (Figure 1-9) as well as floodplain areas within Copperas Brook from TP-3 to the outlet of TP-1 will be impacted by the cleanup action. These impacts are unavoidable as there are no practicable alternatives to the cleanup activities. The wetlands in these areas will be completely removed (destroyed). As a result, mitigation of the wetlands will be included in the design. Any floodplain impacts will be mitigated by

designing a final surface water flow system that will have equal or better flood storage capacity. The cleanup action will also result in the dredging and filling of wetlands and waters of the U.S. Portions of Copperas Brook will be altered and re-located to separate Copperas Brook from the tailings. The re-location is unavoidable as the natural channel is beneath the tailings and removal of the two million cubic yards of tailings is considered impracticable.

Adverse Effect to a Historic Resource

Section 106 of the NHPA of 1966, as amended (16 USC 470f), requires EPA to take into account the effects of all actions on historic properties that have been determined to be eligible for the National Register of Historic Places. In order to be considered eligible, the site must meet at least one of four significance criteria and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, and in accordance with 36 CFR Part 60, the EPA has determined the Elizabeth Mine Site eligible for the National Register. The EPA has determined the site's significance to be best reflected by Criterion A: *those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Construction activities considered in this EE/CA will have direct and indirect impacts on features of the historic property at the Elizabeth Mine Site. EPA has determined that these impacts are unavoidable and necessary to protect human health and the environment. The preliminary APE for direct effects is shown in Figure 3-2. The APE will be further defined to address indirect effects, cumulative effects and other effects when a removal option is selected and the construction design is completed. EPA will work with the SHPO and other consulting parties to develop a MOA between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

VT Solid Waste Management Rules

Findings with respect to the VT Solid Waste Management Rules:

EPA has determined that certain requirements of the VTSWMR cannot be met in order to implement the cleanup action consistent with historic preservation and community concerns regarding truck traffic and cost. EPA is making the finding that alternative measures can be taken in implementing the remedy given that:

- The proposed alternative measures to the requirements of the VTSWMR will not endanger or tend to endanger human health or safety. The design, installation, and perpetual maintenance of measures to collect and treat all of the run-off from the portion of TP-3 that is retained for historic preservation purposes, would result in the protection of the aquatic resources of the WBOR as well as human health and safety with respect to the release of AMD at the Site. The alternative measures proposed for the final grade and slope cover systems for TP-1 and TP-2 would not endanger human health or safety since the cover system that will be implemented will have an equivalent level of protection as the cover system that was specified in the VTSWMR;

- Compliance with certain VTSWMR would produce serious hardship by causing the destruction of certain areas targeted for historic preservation without equal or greater benefit to the public. The alternative measures proposed for final grading and the slope cover system of TP-1 and TP-2 would have equal or greater benefit to public health and the environment while reducing the serious hardship to the historic resources at the Site. The alternative measure for the preservation of TP-3 would also have equal or greater benefit to public health and the environment while reducing the serious hardship to the historic resources at the Site;

- The material at the Site is not considered to be a hazardous waste subject to regulation under the Resource Conservation and Recovery Act (RCRA) Subtitle C; and

- There is no practicable means known or available to meet both the historic preservation requirements and certain requirements of the VTSWMR, however, the substitute or alternative measures proposed in this cleanup plan would achieve an equivalent level of protection of public health and the environment.

The specific alternative measures proposed to the particular requirements of the VT SWMR are detailed below:

- The design of the cleanup will determine the appropriate surface and slope grades at the Site as opposed to the minimum grade of 5% and the maximum grade of 33% specified in the VTSWMR. Performance objectives for the grading will be to: minimize ponding on the barrier layer and promote run-off; minimize erosion; minimize AMD generation; and optimize slope steepness in the interest of historic preservation.

- Final closure of exposed waste rock and heap leach piles would not be required for TP-3. EPA would design and construct a collection and treatment system to address the run-off from TP-3. The change is dependent upon VTANR accepting the responsibility for the maintenance of the treatment system.

- Cleanup alternatives will not be required to include an infiltration barrier on the slopes of TP-1 or TP-2 if the design determines the infiltration barrier to be unnecessary to stabilize the slopes, minimize erosion, and minimize AMD generation.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc. (40 CFR 202, 203, 205); however, they are not considered ARARs for the purposes of this EE/CA.

4.2.2 Effectiveness (2B)

4.2.2.1 Long-term Effectiveness and Permanence (2B)

Alternative 2B achieves long-term effectiveness and permanence by the following:

TP-3

The long-term effectiveness and permanence of the passive treatment systems is entirely dependent upon the implementation of the necessary long-term monitoring and maintenance activities. These systems if properly designed, constructed, monitored and maintained should function successfully for as long as they are needed. Compliance criteria should be met for as long as these systems are properly monitored and maintained. The long-term effectiveness and permanence for the portion of TP-3 that is removed is evaluated below.

TP-1 and TP-2 and portions of TP-3 that are re-located to TP-1

The long-term effectiveness and permanence of surface water diversion, cap, and passive treatment system for TP-1 (including the re-located portions of TP-3) is also dependent on monitoring and maintenance. However, the surface water diversions and cap can function highly effectively with minimal maintenance, whereas the passive treatment system is more maintenance dependent. For the area of TP-1, the cap system will essentially eliminate surface water infiltration into the tailings and the perimeter diversion channels will intercept shallow ground water flow into the tailings. The estimated seepage quantity at the toe of the combined tailings pile is estimated to be about five- ten gpm. The seepage will be collected with a toe-drain system and treated with the passive treatment system. The cap will also effectively prevent exposure to the tailings.

4.2.2.2 Reduction of Toxicity, Mobility, or Volume Through Treatment (2B)

The passive treatment systems installed for treatment of the run-off from TP-3 and TP-1 will reduce the toxicity, mobility, and volume through treatment of contaminants by transforming soluble (and bioavailable) forms of metals into insoluble forms within the organic substrate. Passive treatment systems are designed to precipitate metal sulfides from solution through biologically-mediated reactions. Once in a sulfide form at near-neutral pH, copper and zinc (as examples) remain highly insoluble. Maintaining neutral pH is important in this substrate to retain the metals in sulfide form.

The surface water diversion and cap do accomplish a reduction in the volume of AMD and reduce the mobility of contaminants with the tailings, however, this benefit is achieved through containment, not treatment.

4.2.2.3 Short-Term Effectiveness (2B)

Alternative 2B achieves short-term effectiveness by the following:

TP-3

For TP-3, the improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. If funding for the NTCRA is received in 2002, the passive treatment systems could be installed by 2003 or 2004. Short-term impacts to floodplains, stream channels, and wetlands will be alleviated upon completion of the new stream channels and floodplain areas and restoration of the wetlands. Some short-term impacts to the community will occur from construction disturbances and truck traffic. The removal of the high metal-sulfide waste rock, if the Vermont ANR chooses TP-3 Options 2 or 3, would also have a direct positive effect by reducing the area of surface water contributing to the passive treatment systems, thereby reducing the long term loading to the passive treatment systems for TP-3.

TP-1 and TP-2

The reduction in erosion and dust will be evident immediately upon placement of the cap. Further improvements will take place once the passive treatment systems are operational. In addition, a substantial decrease in the volume of flow into the TP-1 passive treatment system should occur within five years of the diversion ditch and cap installation being complete. Alternative 2B does involve the moving and regrading of the tailings, which will lead to the temporary exposure of fresh tailings over a wide area. The use of air monitoring and engineering controls, such as dust suppression and covering the tailings, will minimize any potential risks to nearby residents and the environment. Daily surface covers will be applied to reduce or eliminate exposure to the elements. Surface covers may include impervious tarps or a spray-on fixation compound. Such compounds have been tested at mining sites in the past with success, using locally available materials, such as power plant fly-ash and cement kiln dust. The design stage will fully evaluate options for construction safety needs. The exposure of large quantities of unoxidized tailings also creates the potential for major impacts to Copperas Brook and the WBOR if a storm event were to overwhelm the sediment and erosion control measures at the Site. Careful implementation and substantial erosion control measures will be necessary during construction to minimize the potential for this situation to occur.

Alternative 2B requires considerable truck traffic at various stages. Material movement from TP-2 to TP-1 and from TP-3 to TP-1 would occur over a period of several months and require continuous truck traffic during working hours along a small portion of Mine Road, unless an alternate route is identified. Regrading of the tailings will involve considerable on-site truck and heavy machinery traffic over several months. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Construction of the proposed cap, diversion channels and passive treatment systems will require approximately 7,765 trucks over a six-month period to deliver the necessary materials. The road weight limits could even increase the truck numbers. On-site heavy equipment operations would be necessary throughout this period. Indirect and direct impacts to the surrounding towns, including Norwich, Sharon, Strafford, and Thetford, may be observed through increased truck traffic, noise, dust, and road surface degradation. Soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect the amount of truck traffic. If a soil borrow pit is identified near the Site, truck traffic on local roads would be reduced if roads can be constructed through the woods from the Site to the soil borrow pit.

EPA will work with the local community to develop a traffic control plan that minimizes the impact of truck traffic to the extent practical.

4.2.3 Implementability (2B)

4.2.3.1 Technical Feasibility (2B)

Significant concerns with respect to the passive treatment system are: winter performance, the longevity of the treatment components, and the ability of the system to achieve water quality standards. Accomplishing the treatment of AMD through a passive or semi-passive system appears within reach of existing technologies. The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for copper.

EPA’s expectation is that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. Data from pilot-scale treatability studies will be used to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal. EPA believes it is technically feasible to design a passive and/or semi-passive treatment system for the TP-3 contamination that has a reasonable probability of success. These issues must be addressed during the design.

Design and construction of the Alternative 2B cap system (cap, diversion, and slope stability) uses proven and easily implemented technologies. It is technically feasible to design and construct a cap system that will meet the response objectives and EPA’s technical guidance on final covers. The technical activities associated with moving and regrading large quantities of the tailings are more complicated but can be implemented with careful planning.

The ability to design, construct and operate a passive system to handle the anticipated flows is technically feasible. However, winter conditions in Vermont will impact the functionality of passive/natural treatment systems to some extent. Surface runoff that contacts TP-3 tailings is minimal through much of December, all of January/February, and much of March (25 to 30% of the year). Summer flow is generally very low to non-existent. Recent studies by Montana Tech (K. Burgher, 2001, Personal Communication, and ICARD 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. Aerobic system functionality (polishing steps) may also be reduced due to thick ice cover and subsequent reduction in available oxygen. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged during winter months. Such innovative passive/natural treatment systems would promote sustainable operations, biological diversity, and minimize operational and maintenance costs. The technology associated with the passive treatment system has been successfully implemented at a number of sites in the U.S. After the cap system and the diversion channels are constructed, the seepage at the toe of the combined tailings will be on the order of five gpm. For TP-3, the contaminated surface runoff and ground water seepage will have a high range of flow conditions. Preliminary design concepts call for a flow basis ranging from 20 to 40 gpm. The flow is to be handled by appropriate sizing of the passive treatment system and conservative sizing of the holding pond that will allow significant storage while treating at variable rates. The holding pond and passive treatment system sizing allows for complete capture of runoff from a 100-year, 24-hour storm event.

During the winter months of December through mid-March, construction work is unlikely due to snow cover and frozen ground.

4.2.3.2 Administrative Feasibility (2B)

Alternative 2B is administratively feasible. Implementation of Alternative 2B will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Coordination will be needed with the Vermont Department of Transportation and local community relative to traffic disruption and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Strafford, Sharon, Norwich, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the Town Select Board.

4.2.3.3 Availability of Services and Materials (2B)

Services and materials to implement alternative 2B are available. The excavation, transport, and regrading of tailings, and the construction of diversion channels and passive treatment systems will be performed using conventional construction equipment and techniques. Approximately 75,000 cubic yards of common borrow material, topsoil, aggregate, and limestone is required for this alternative. All of the material, except limestone, is available in sufficient quantities from many sources within 30 miles of the Site. Limestone must be transported from central Vermont. Multiple trucking/transportation contractors will be required. Local (i.e., Vermont/New Hampshire) contractors are available for earthmoving and construction activities.

Water is available from the WBOR at Tyson’s Bridge, about 1½ miles from TP-1. Electric service is available at the main entrance to the Site.

Commercial testing laboratories are readily available throughout New England.

4.2.3.4 State and Community Acceptance (2B)

EPA has actively involved the state and community in the alternatives identification process at the Elizabeth Mine Site. EPA, VTANR, and the Elizabeth Mine Community Advisory Group (EMCAG) have been meeting regularly since April 2000. The formal evaluation of state and community acceptance will be addressed following VTANR, SHPO, and public review of this EE/CA.

Based on the past two years of discussion and meetings, EPA is providing this summary of “Concerns Expressed to Date”: In February 2000, EPA held a public meeting to discuss a proposed early cleanup action at the Site. Many individuals in the community were concerned that the pace of the project, as proposed, would not provide the public with the level of involvement sought by the community. In response to these concerns, and a strong desire for local involvement, the communities of Strafford and Thetford formed the EMCAG to advise the EPA and ANR regarding community concerns related to the proposed cleanup. The EMCAG has been meeting since April 2000 and has taken an active role in cleanup discussions. The EE/CA Report, along with the previously released *Site Conditions Report*, *Historical Report*, *Alternative Analysis Report*, and the *Preliminary Ecological and Human Health Risk Assessment Reports* are outcomes of the EPA and VTANR dialogue with the EMCAG. The reports provided the public with a substantial opportunity for early involvement in the assessment of the Site conditions, the nature of the hazards, the historic resources at the Site, and the identification of the cleanup alternatives that are evaluated in this EE/CA.

Since February 2000, the community expressed concerns regarding the total cost of the project, the historical significance of the Site, the time period required to design and implement a cleanup action, and the construction related truck traffic that would be required to transport the equipment and material to the Site. The following actions were undertaken in preparation of this EE/CA report to satisfy some of the community concerns:

- The costs included in this report reflect local vendor prices.
- Each alternative was designed to minimize impact to the historical resources of the Site.
- The volume of material used in each alternative represents as low a volume as practical to achieve the remedial action objectives; therefore, the truck numbers are considered the lowest possible.

State and Community acceptance will be further evaluated upon closure of the public comment period.

4.2.4 Cost (2B)

The capital costs and PRSC are summarized under Alternative 2B in the following table. The cost breakdown and cost assumptions are provided in Appendix C.

Elizabeth Mine Cleanup Cost Table		
Cleanup Alternatives		**2B Infiltration Barrier Cap (Geomembrane) on TP-1 and Remove TP-2**
Capital Costs	Option 1	$13,629,811
	Option 2	$15,153,866
	Option 3	$16,200,818
PRSC Activity	TP-1 Maintenance	$82,220
	TP-3 Maintenance (Option 1 - Complete Preservation of TP-3)	$254,359-$400,523
	TP-3 Maintenance (Option 2/3 – Preservation of 20% - 50% of TP-3)	$153,259-$200,940
Total Annual State Costs	Based on TP-1 and TP-3 Option 1	$336,579-$482,743
	Based on TP-1 and TP-3 Option 2/3	$235,479-$283,161

Add all 3 TP-3 options and nominal costs for replacement

4.3 Alternative 2C

4.3.1 Description (2C)

Alternative 2C has the same objectives as Alternative 2B except that TP-2 is retained. See Figure 3-3 for Alternative 2C conceptual drawing and Section 3 for a detailed description of Alternative 2C.

4.3.2 Effectiveness (2C)

The following section provides a detailed analysis of the effectiveness of Alternative 2C.

4.3.2.1 Overall Protection of Human Health and the Environment (2C)

Alternative 2C achieves overall protection of human health and the environment by the following:

TP-3

For TP-3, overall protection of human health and the environment is accomplished through the collection of the discharge (run-off and groundwater) from the waste rock and heap leach piles of TP-3 and subsequent treatment of this water in a treatment system. The passive treatment system will treat the collected water to meet VTWQS. The result will be a discharge to Copperas Brook and the WBOR that no longer has an adverse impact on these receiving waters. As TP-3 will remain exposed, ongoing erosion must be an accepted condition of long-term performance if the historical integrity of the tailings is to be preserved. Some exposure to site contaminants would occur as a result of long-term human contact and wind blown transport of the waste rock, and heap leach piles within TP-3. The concentration of metals found in TP-3 are not above levels that would warrant measures to prevent exposure to this material. Further studies of TP-3 will be performed during design to confirm that the material in TP-3 does not represent a threat to human health. Any waste rock or heap leach piles removed from TP-3 will be placed under the cover system for TP-1. This material will no longer be a source for AMD.

TP-1 and TP-2

For TP-1 and TP-2, overall protection of human health and the environment is accomplished through the covering of the exposed tailings, stabilization of the steep slopes, and reduction in the generation of AMD. The vegetated soil cover over the tailings will effectively stabilize the tailings surface to prevent windblown transport of dust and minimize erosion. Stabilization of the slopes of TP-1 and TP-2 would occur if design studies indicate a potential for failure of the tailings or cover system at the current slope configuration. The filling of the decant pipes will further improve the stability of TP-1. The cap and perimeter diversion ditch will effectively minimize the amount of water entering the TP-1 resulting in a dramatic reduction in AMD from TP-1. The estimated long-term ground water influx into the combined tailings will be on the order of five-ten gpm; so the seepage at the toe of the combined tailings pile will be on the order of five-ten gpm (possibly less). The seepage will be collected with a toe-drain system and treated using the passive treatment system. The effluent of the passive treatment is expected to meet the discharge criteria, which will be based upon VTWQS.

4.3.2.2 Compliance With ARARs and Other Criteria, Advisories, and Guidance (2C)

Table 4-2 identifies the ARARs that apply to Alternative 2C. Alternative 2C would comply with all federal and state location-, chemical-, and action-specific ARARs that apply to the Site. This compliance determination is dependent upon the final implementation of a rule change to the VTSWMR. None of the alternatives comply with the current VTSWMR, however, the VTANR has issued a proposed rule change for public comment and has committed to finalizing the rule change such that the revised rule will be in effect prior to the signing of the EPA Action Memorandum. As a result, EPA has evaluated the VTSWMR based upon the assumed rule change. If the VTSWMR is not revised, then the EE/CA must be revised to assess ARAR compliance. As part of the ARAR evaluation, EPA is specifically seeking public comment on the following:

Unavoidable impacts to Wetlands and Floodplain:

> The Wetlands below TP-1, on the surface of TP-1, adjacent to the adit, and within the stream channel of Copperas Brook from TP-3 to the outlet of TP-1 (see Figure 1-9) as well as floodplain areas within Copperas Brook from TP-3 to the outlet of TP-1 will be impacted by the cleanup action. These impacts are unavoidable as there are no practicable alternatives to the cleanup activities. The wetlands in these areas will be completely removed (destroyed). As a result, mitigation of the wetlands will be included in the design. Any floodplain impacts will be mitigated by designing a final surface water flow system that will have equal or better flood storage capacity. The cleanup action will also result in the dredging and filling of wetlands and waters of the U.S. Portions of Copperas Brook will be altered and re-located to separate Copperas Brook from the tailings. The re-location is unavoidable as the natural channel is beneath the tailings and removal of the two million cubic yards of tailings is considered impracticable.

Adverse Effect to a Historic Resource

> Section 106 of the NHPA of 1966, as amended (16 USC 470f), requires EPA to take into account the effects of all actions on historic properties that have been determined to be eligible for the National Register of Historic Places. In order to be considered eligible, the site must meet at least one of four significance criteria and possess integrity among some of the following qualities: original location, design, setting,

workmanship, materials, or feelings and association. In consultation with the SHPO, and in accordance with 36 CFR Part 60, the EPA has determined the Elizabeth Mine Site eligible for the National Register. The EPA has determined the site's significance to be best reflected by Criterion A: *those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Construction activities considered in this EE/CA will have direct and indirect impacts on features of the historic property at the Elizabeth Mine Site. EPA has determined that these impacts are unavoidable and necessary to protect human health and the environment. The preliminary APE for direct effects is shown in Figure 3-3. The APE will be further defined to address indirect effects, cumulative effects and other effects when a removal option is selected and the construction design is completed. EPA will work with the SHPO and other consulting parties to develop a MOA between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

VT Solid Waste Management Rules

Findings with respect to the VT Solid Waste Management Rules:

EPA has determined that certain requirements of the VTSWMR cannot be met in order to implement the cleanup action consistent with historic preservation and community concerns regarding truck traffic and cost. EPA is making the finding that alternative measures can be taken in implementing the remedy given that:

- The proposed alternative measures to the requirements of the VTSWMR will not endanger or tend to endanger human health or safety. The design, installation, and perpetual maintenance of measures to collect and treat all of the run-off from the portion of TP-3 that is retained for historic preservation purposes, would result in the protection of the aquatic resources of the WBOR as well as human health and safety with respect to the release of AMD at the Site. The alternative measures proposed for the final grade and slope cover systems for TP-1 and TP-2 would not endanger human health or safety since the cover system that will be implemented will have an equivalent level of protection as the cover system that was specified in the VTSWMR;

- Compliance with certain VTSWMR would produce serious hardship by causing the destruction of certain areas targeted for historic preservation without equal or greater benefit to the public. The alternative measures proposed for final grading and the slope cover system of TP-1 and TP-2 would have equal or greater benefit to public health and the environment while reducing the serious hardship to the historic resources at the Site. The alternative measure for the preservation of TP-3 would also have equal or greater benefit to public health and the environment while reducing the serious hardship to the historic resources at the Site;

- The material at the Site is not considered to be a hazardous waste subject to regulation under the Resource Conservation and Recovery Act (RCRA) Subtitle C; and

- There is no practicable means known or available to meet both the historic preservation requirements and certain requirements of the VTSWMR, however, the substitute or alternative measures proposed in this cleanup plan would achieve an equivalent level of protection of public health and the environment.

The specific alternative measures proposed to the particular requirements of the VTSWMR are detailed below:

- The design of the cleanup will determine the appropriate surface and slope grades at the Site as opposed to the minimum grade of 5% and the maximum grade of 33% specified in the VTSWMR. Performance objectives for the grading will be to: minimize ponding on the barrier layer and promote run-off; minimize erosion; minimize AMD generation; and optimize slope steepness in the interest of historic preservation.

- Final closure of exposed waste rock and heap leach piles would not be required for TP-3. EPA would design and construct a collection and treatment system to address the run-off from TP-3. The change is dependent upon VTANR accepting the responsibility for the maintenance of the treatment system.

- Cleanup alternatives will not be required to include an infiltration barrier on the slopes of TP-1 or TP-2 if the design determines the infiltration barrier to be unnecessary to stabilize the slopes, minimize erosion, and minimize AMD generation.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc. (40 CFR 202, 203, 205); however, they are not considered ARARs for the purposes of this EE/CA.

4.3.2.3 Long-term Effectiveness and Permanence (2C)
Alternative 2C achieves long-term effectiveness and permanence by the following:

TP-3
The long-term effectiveness and permanence of the passive treatment systems is entirely dependent upon the implementation of the necessary long-term monitoring and maintenance activities. These systems if properly designed, constructed, monitored and

maintained should function successfully for as long as they are needed. Compliance criteria should be met for as long as these systems are properly monitored and maintained.

TP-1 and TP-2

The long-term effectiveness and permanence of surface water diversion, multi-barrier cap, and passive treatment system for TP-1 and TP-2 is also dependent on monitoring and maintenance. However, the surface water diversions and cap can function highly effectively with minimal maintenance, whereas the passive treatment system is more maintenance dependent. For the area of TP-1 and TP-2, the cap system will essentially eliminate surface water infiltration into the tailings and the perimeter diversion channels will intercept shallow ground water flow into the tailings. The estimated seepage quantity at the toe of the combined tailings pile is estimated to be about five-ten gpm. The seepage will be collected with a toe-drain system and treated with the passive treatment system. The cap will also effectively prevent exposure to the tailings.

4.3.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment (2C)

The passive treatment systems installed for treatment of the run-off from TP-3 and TP-1 and TP-2 will reduce the toxicity, mobility, and volume through treatment of contaminants by transforming soluble (and bioavailable) forms of metals into insoluble forms within the organic substrate. Passive Treatment systems are designed to precipitate metal sulfides from solution through biologically-mediated reactions. Once in a sulfide form at circum-neutral pH, copper and zinc (as examples) remain highly insoluble. Maintaining neutral pH is important in this substrate to retain the metals in sulfide form.

The surface water diversion and cap do accomplish a reduction in the volume of AMD and reduce the mobility of contaminants with the tailings; however, this benefit is achieved through containment, not treatment.

4.3.2.5 Short-Term Effectiveness (2C)

Alternative 2C achieves short-term effectiveness by the following:

TP-3

For TP-3, the improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. If funding is available in 2002, the passive treatment systems could be installed by 2003 or 2004. Short-term impacts to floodplains, stream channels, and wetlands will be alleviated upon completion of the new stream channels and floodplain areas and restoration of the wetlands. Some short-term impacts to the community will occur from construction disturbances and truck traffic. The removal of the high metal-sulfide waste rock, if VTANR chooses TP-3 Options 2 or 3, would also have a direct positive effect by reducing the area of surface water contributing to the passive treatment systems, thereby reducing the long term loading to the passive treatment systems for TP-3.

TP-1 and TP-2
The reduction in erosion and dust will be evident immediately upon placement of the cap. The improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. In addition, a substantial decrease in the volume of flow into the TP-1 and TP-2 passive treatment system should occur within five years of the diversion ditch and cap installation being complete. Alternative 2C does involve the moving and regrading of the tailings which will lead to the temporary exposure of fresh tailings over a wide area. The use of air monitoring and engineering controls, such as dust suppression and covering the tailings, will minimize any potential risks to nearby residents and the environment. Daily surface covers will be applied to reduce or eliminate exposure to the elements. Surface covers may include impervious tarps or a spray-on fixation compound. Such compounds have been tested at mining sites in the past with success, using locally available materials, such as power plant fly ash and cement kiln dust. The design stage will fully evaluate options for construction safety needs.

Alternative 2C requires considerable truck traffic at various stages. Material movement from TP-2 to TP-1 would occur over a period of several months and require continuous truck traffic during working hours along a small portion of Mine Road, unless an alternate route is identified. Regrading of the tailings will involve considerable on-site truck and heavy machinery traffic over several months. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Construction of the proposed cap, diversion channels and passive treatment systems will require approximately 7,765 trucks over a six-month period to deliver the necessary materials for the cover system. The road weight limits could even increase the truck numbers. On-site heavy equipment operations would be necessary throughout this period. Indirect and direct impacts to the surrounding towns, including Norwich, Sharon, Strafford, and Thetford, would be observed through increased truck traffic, noise, dust, and road surface degradation. Soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect the amount of truck traffic. If a soil borrow pit is identified near the Site, truck traffic on local roads would be reduced if roads can be constructed through the woods from the Site to the soil borrow pit.

EPA will work with the local community to develop a traffic control plan that minimizes the impact of truck traffic to the extent practical.

4.3.3 Implementability (2C)

4.3.3.1 Technical Feasibility (2C)
Significant concerns with respect to the passive treatment system are: winter performance, the longevity of the treatment components, and the ability of the system to achieve water quality standards. Accomplishing the treatment of AMD through a

passive or semi-passive system appears within reach of existing technologies. The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for copper.

EPA's expectation is that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. Data from pilot-scale treatability studies will be used to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal. EPA believes it is technically feasible to design a passive and/or semi-passive treatment system for the TP-3 contamination that has a reasonable probability of success. These issues must be addressed during the design.

Design and construction of the cap system for Alternative 2C (cap, diversion, and slope stability) uses proven and easily implemented technologies. It is technically feasible to design and construct a cap system that will meet the response objectives and EPA's technical guidance on final covers.

The ability to design, construct and operate a passive system to handle the anticipated flows is technically feasible. However, winter conditions in Vermont will impact the functionality of passive/natural treatment systems to some extent. Surface runoff that contacts TP-3 tailings is minimal through much of December, all of January/February, and much of March (25 to 30% of the year). Summer flow is generally very low to non-existent. Recent studies by Montana Tech (K. Burgher, 2001, Personal Communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. Aerobic system functionality (polishing steps) may also be reduced due to thick ice cover and subsequent reduction in available oxygen. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged during winter months.

Such innovative passive/natural treatment systems would promote sustainable operations, biological diversity, and minimize operational and maintenance costs. The technology associated with the passive treatment system has been successfully implemented at a number of sites in the U.S. After the cap system and the diversion channels are constructed, the seepage at the toe of the combined tailings will be on the order of 5 gpm. For TP-3, the contaminated surface runoff and ground water seepage will have a high range of flow conditions. Preliminary design concepts call for a flow basis ranging from 20 to 40 gpm. The flow is to be handled by appropriate sizing of SAPS and conservative sizing of the holding pond that will allow significant storage while treating at variable rates. The holding pond and passive treatment system sizing allows for complete capture of runoff from a 100-year, 24-hour storm event.

During the winter months of December through mid-March, construction work is unlikely due to snow cover and frozen ground.

4.3.3.2 Administrative Feasibility (2C)

Alternative 2C is administratively feasible. Implementation of Alternative 2C will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Coordination will be needed with the Vermont Department of Transportation and local community relative to traffic disruption and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Strafford, Sharon, Norwich, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the Town Select Board.

4.3.3.3 Availability of Services and Materials (2C)

Services and materials to implement alternative 2C are available. The excavation, transport, and regrading of tailings, and the construction of diversion channels and passive treatment systems will be performed using conventional construction equipment and techniques. Approximately 80,000 cubic yards of common borrow material, topsoil, aggregate, and limestone is required for this alternative. Multiple trucking/transportation contractors will be required. Local (i.e., Vermont/New Hampshire) contractors are available for earthmoving and construction activities.

Water is available from the WBOR at Tyson's Bridge, about 1½ miles from TP-1. Electric service is available at the main entrance to the Site. Commercial testing laboratories are readily available throughout New England.

4.3.3.4 State and Community Acceptance (2C)

EPA has actively involved the state and community in the alternatives identification process at the Elizabeth Mine Site. EPA, VTANR, and the EMCAG have been meeting regularly since April 2000. The formal evaluation of state and community acceptance will be addressed following VTANR, SHPO, and public review of this EE/CA.

Based on the past two years of discussion and meetings, EPA is providing this summary of "Concerns Expressed to Date": In February 2000, EPA held a public meeting to discuss a proposed early cleanup action at the Site. Many individuals in the community were concerned that the pace of the project, as proposed, would not provide the public with the level of involvement sought by the community. In response to these concerns, and a strong desire for local involvement, the communities of Strafford and Thetford formed the EMCAG to advise the EPA and ANR regarding community concerns related to the proposed cleanup. The EMCAG has been meeting since April 2000 and has taken an active role in cleanup discussions. The EE/CA Report, along with the previously released *Site Conditions Report*, *Historical Report*, *Alternative Analysis Report*, and the *Preliminary Ecological and Human Health Risk Assessment Reports* are outcomes of the EPA and VTANR dialogue with the EMCAG. The reports provided the public with a substantial opportunity for early involvement in the assessment of the Site conditions, the nature of the hazards, the historic resources at the Site, and the identification of the cleanup alternatives that are evaluated in this EE/CA.

Since February 2000, the community expressed concerns regarding the total cost of the project, the historical significance of the Site, the time period required to design and implement a cleanup action, and the construction related truck traffic that would be required to transport the equipment and material to the Site. The following actions were undertaken in preparation of this EE/CA report to satisfy some of the community concerns:

- The costs included in this report reflect local vendor prices.
- Each alternative was designed to minimize impact to the historical resources of the Site.
- The volume of material used in each alternative represents as low a volume as practical to achieve the remedial action objectives; therefore, the truck numbers are considered the lowest possible.

State and Community acceptance will be further evaluated upon closure of the public comment period.

4.3.4 Cost (2C)

The capital costs and PRSC are summarized for each option in the following table. The cost breakdown and cost assumptions are provided in Appendix C.

Elizabeth Mine Cleanup Cost Table		
Cleanup Alternatives		**2C Infiltration Barrier Cap (Geomembrane) on TP-1 and TP-2**
Capital Costs	Option 1	$12,902,894
	Option 2	$14,426,949
	Option 3	$15,473,901
PRSC Activity	TP-1 Maintenance	$89,974
	TP-3 Maintenance (Option 1 - Complete Preservation of TP-3)	$254,359-$400,523
	TP-3 Maintenance (Option 2/3 – Preservation of 20% - 50% of TP-3)	$153,259-$200,940
Total Annual State Costs	Based on TP-1 and TP-3 Option 1	$344,333-$490,498
	Based on TP-1 and TP-3 Option 2/3	$243,234-$290,915

4.4 Alternative 3B

4.4.1 Description (3B)

Alternative 3B has the same objectives as Alternative 2C, but uses an evapotranspiration (ET) cover of sufficient thickness for evaporation and plant transpiration to reduce rain water infiltration, instead of a multi-layer cap system that is designed for the complete elimination of infiltration. Analyses indicate that a minimum cover thickness of approximately 42 inches is needed to achieve the ET performance requirements for Vermont. This consists of 36 inches of common borrow material with a six-inch topsoil cover, capable of supporting a diverse plant population, including trees.

Surface drainage will follow the original surface flow patterns across the tailings and clean storm-water will be collected and discharged through the perimeter diversion channels without impacting any other features of historic importance. A toe drain will be installed to collect the seepage at the toe of TP-1 and TP-2. The collected water will be treated with the passive/natural treatment system.

Construction of an ET cover of 42 inches would significantly increase the trucks required for delivering soils and other construction materials to approximately 17,992 truck trips over the period of construction. This will significantly increase the direct and indirect adverse effect on the surrounding towns and residents, including noise, dust, and road degradation. See Figure 3-4 for Alternative 3B conceptual drawing and Section 3 for a detailed description of Alternative 3B.

4.4.2 Effectiveness (3B)

The following section provides an analysis of the effectiveness of Alternative 3B.

4.4.2.1 Overall Protection of Human Health and the Environment (3B)

Alternative 3B achieves overall protection of human health and the environment by the following:

TP-3

For TP-3, overall protection of human health and the environment is accomplished through the collection of the discharge (run-off and groundwater) from the waste rock and heap leach pile of TP-3 and subsequent treatment of this water in a treatment system. The passive treatment system will treat the collected water to meet VTWQS. The result will be a discharge to Copperas Brook and the WBOR that no longer has an adverse impact on these receiving waters. Since TP-3 will remain exposed, ongoing erosion must be an accepted condition of long-term performance if the historical integrity of the tailings is to be preserved. Some exposure to site contaminants would occur as a result of long-term human contact and wind blown transport of the waste rock and heap leach piles within TP-3. The concentration of metals found in TP-3 are not above levels that would warrant measures to prevent exposure to this material. Further studies of TP-3 will be performed during design to confirm that the material in TP-3 does not represent a threat to human health. Any waste rock or heap leach piles removed from TP-3 will be placed under the cover system for TP-1. This material will no longer be a source for AMD.

TP-1 and TP-2

For TP-1 and TP-2, overall protection of human health and the environment is accomplished through the covering of the exposed tailings, stabilization of the steep slopes, and reduction in the generation of AMD. A vegetated soil cover or rock cover over the tailings will effectively stabilize the tailings surface to prevent windblown transport of dust and minimize erosion. The filling of the decant pipes will further improve the stability of TP-1. The soil cover and perimeter diversion ditch will effectively minimize the amount of water entering the TP-1 resulting in a dramatic reduction in AMD from TP-1. The residual flow from the seeps of TP-1 and TP-2 are expected to be approximately 15 gpm. The effluent of the passive treatment is expected to meet the discharge criteria, which will be based upon VTWQS.

4.4.2.2 Compliance With ARARs and Other Criteria, Advisories, and Guidance (3B)

Table 4-2 identifies the ARARs that apply to Alternative 3B. Alternative 3B would comply with all federal and state location-, chemical-, and action-specific ARARs that apply to the Site. This compliance determination is dependent upon the final implementation of a rule change to the VTSWMR. None of the alternatives comply with the current VTSWMR, however, the VTANR has issued a proposed rule change for public comment and has committed to finalizing the rule change such that the revised rule will be in effect prior to the signing of the EPA Action Memorandum. As a result, EPA has evaluated the VTSWMR based upon the assumed rule change. If the VTSWMR is not revised, then the EE/CA must be revised to assess ARAR compliance. This alternative would only comply with the VTSWMR if the bottom 18 inches of the cover system meet a performance requirement of a permeability of 1 x 10^{-5} cm/sec or less As part of the ARAR evaluation, EPA is specifically seeking public comment on the following:

Unavoidable Impacts to Wetlands and Floodplain:

The Wetlands below TP-1, on the surface of TP-1, adjacent to the adit, and within the stream channel of Copperas Brook from TP-3 to the outlet of TP-1 (Figure 1-9) as well as floodplain areas within Copperas Brook from TP-3 to the outlet of TP-1 will be impacted by the cleanup action. These impacts are unavoidable as there are no practicable alternatives to the cleanup activities. The wetlands in these areas will be completely removed (destroyed). As a result, mitigation of the wetlands will be included in the design. Any floodplain impacts will be mitigated by designing a final surface water flow system that will have equal or better flood storage capacity. The cleanup action will also result in the dredging and filling of wetlands and waters of the U.S. Portions of Copperas Brook will be altered and re-located to separate Copperas Brook from the tailings. The re-location is unavoidable as the natural channel is beneath the tailings and removal of the two million cubic yards of tailings is considered impracticable.

Adverse Effect to a Historic Resource

Section 106 of the NHPA of 1966, as amended (16 USC 470f), requires EPA to take into account the effects of all actions on historic properties that have been determined to be eligible for the National Register of Historic Places. In order to be considered eligible, the site must meet at least one of four significance criteria and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, and in accordance with 36 CFR Part 60, the EPA has determined the Elizabeth Mine Site eligible for the National Register. The EPA has determined the site's significance to be best reflected by Criterion A: *those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Construction activities considered in this EE/CA will have direct and indirect impacts on features of the historic property at the Elizabeth Mine Site. EPA has determined that these impacts are unavoidable and necessary to protect human health and the environment. The preliminary APE for direct effects is shown in Figure 3-4. The APE will be further defined to address indirect effects, cumulative effects and other effects when a removal option is selected and the construction design is completed. EPA will work with the SHPO and other consulting parties to develop a MOA between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

VT Solid Waste Management Rules

Findings with respect to the VT Solid Waste Management Rules:

EPA has determined that certain requirements of the VTSWMR cannot be met in order to implement the cleanup action consistent with historic preservation and community concerns regarding truck traffic and cost. EPA is making the finding that alternative measures can be taken in implementing the remedy given that:

- The proposed alternative measures to the requirements of the VTSWMR will not endanger or tend to endanger human health or safety. The design, installation, and perpetual maintenance of measures to collect and treat all of the run-off from the portion of TP-3 that is retained for historic preservation purposes, would result in the protection of the aquatic resources of the WBOR as well as human health and safety with respect to the release of AMD at the Site. The alternative measures proposed for the final grade and slope cover systems for TP-1 and TP-2 would not endanger human health or safety since the cover system that will be implemented will have an equivalent level of protection as the cover system that was specified in the VTSWMR;

- Compliance with certain VTSWMR would produce serious hardship by causing the destruction of certain areas targeted for historic preservation without equal or greater benefit to the public. The alternative measures proposed for final grading and the slope cover system of TP-1 and TP-2 would have equal or greater benefit to public health and the environment while reducing the serious hardship to the historic resources at the Site. The alternative measure for the preservation of TP-3 would also have equal or greater benefit to public health and the environment while reducing the serious hardship to the historic resources at the Site;

- The material at the Site is not considered to be a hazardous waste subject to regulation under the Resource Conservation and Recovery Act (RCRA) Subtitle C; and

- There is no practicable means known or available to meet both the historic preservation requirements and certain requirements of the VTSWMR, however, the substitute or alternative measures proposed in this cleanup plan would achieve an equivalent level of protection of public health and the environment.

The specific alternative measures proposed to the particular requirements of the VTSWMR are detailed below:

- The design of the cleanup will determine the appropriate surface and slope grades at the Site as opposed to the minimum grade of 5% and the maximum grade of 33% specified in the VTSWMR. Performance objectives for the grading will be to: minimize ponding on the barrier layer and promote run-off; minimize erosion; minimize AMD generation; and optimize slope steepness in the interest of historic preservation.

- Final closure of exposed waste rock and heap leach piles would not be required for TP-3. EPA would design and construct a collection and treatment system to address the run-off from TP-3. The change is dependent upon VTANR accepting the responsibility for the maintenance of the treatment system.

- Cleanup alternatives will not be required to include an infiltration barrier on the slopes of TP-1 or TP-2 if the design determines the infiltration barrier to be unnecessary to stabilize the slopes, minimize erosion, and minimize AMD generation.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc. (40 CFR 202, 203, 205); however, they are not considered ARARs for the purposes of this EE/CA.

4.4.2.3 Long-term Effectiveness and Permanence (3B)
Alternative 3B achieves long-term effectiveness and permanence by the following:

TP-3
The long-term effectiveness and permanence of the passive treatment systems is entirely dependent upon the implementation of the necessary long-term monitoring and maintenance activities. These systems if properly designed, constructed, monitored and maintained should function successfully for as long as they are needed. Compliance criteria should be met for as long as these systems are properly monitored and maintained.

TP-1 and TP-2
The long-term effectiveness and permanence of surface water diversion, soil cover, and passive treatment system for TP-1 and TP-2 is also dependent on monitoring and maintenance. However, the surface water diversions and soil cover can function

effectively with minimal maintenance, whereas the passive treatment system is more maintenance dependent. For the area of TP-1 and TP-2, the cap system will reduce surface water infiltration into the tailings and the perimeter diversion channels will intercept shallow ground water flow into the tailings. The estimated seepage quantity at the toe of the combined tailings pile is estimated to be about 15 gpm. The seepage will be collected with a toe-drain system and treated with the passive treatment system. The soil cover will also effectively prevent exposure to the tailings.

4.4.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment (3B)

The passive treatment systems installed for treatment of the run-off from TP-3 and TP-1 and TP-2 will reduce the toxicity, mobility, and volume through treatment of contaminants by transforming soluble (and bioavailable) forms of metals into insoluble forms within the organic substrate. Passive Treatment Systems are designed to precipitate metal sulfides from solution through biologically-mediated reactions. Once in a sulfide form at near-neutral pH, copper and zinc (as examples) remain highly insoluble. Maintaining neutral pH is important in this substrate to retain the metals in sulfide form.

The surface water diversion and cap do accomplish a reduction in the volume of AMD and reduce the mobility of contaminants with the tailings, however, this benefit is achieved through containment, not treatment.

4.4.2.5 Short-Term Effectiveness (3B)

Alternative 3B achieves short-term effectiveness by the following:

TP-3

For TP-3, the improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. If funding is available for the NTCRA in 2002, the passive treatment systems could be installed by 2003 or 2004. Short-term impacts to floodplains, stream channels, and wetlands will be alleviated upon completion of the new stream channels and floodplain areas and restoration of the wetlands. Some short-term impacts to the community will occur from construction disturbances and truck traffic. The removal of the high metal-sulfide waste rock, if VTANR chooses TP-3 Option 2 or 3, would also have a direct positive effect by reducing the area of surface water contributing to the passive treatment systems, thereby reducing the long term loading to the passive treatment systems for TP-3.

TP-1 and TP-2

The reduction in erosion and dust will be evident immediately upon placement of the cap. The improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. In addition, a decrease in the volume of flow into the TP-1 and TP-2 passive treatment system should occur within five years of the diversion ditch and cap installation being complete. Alternative 3B does involve the moving and regrading of the tailings which will lead to the temporary exposure of fresh tailings over a wide area. The use of air monitoring and engineering controls, such as dust suppression and covering the tailings, will minimize any potential risks to nearby residents and the environment. Daily surface covers will be applied to reduce or eliminate exposure to the elements. Surface covers may include impervious tarps or a spray-on fixation compound. Such compounds have been tested at mining sites in the past with success, using locally available materials, such as power plant fly ash and cement kiln dust. The design stage will fully evaluate options for construction safety needs.

Alternative 3B requires considerable truck traffic at various stages. Material movement from TP-2 to TP-1 would occur over a period of several months and require continuous truck traffic during working hours along a small portion of Mine Road, unless an alternate route is identified. Regrading of the tailings will involve considerable on-site truck and heavy machinery traffic over several months. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Construction of the proposed soil cover, diversion channels and passive treatment systems will require approximately 17,992 truck trips over a six-month period to deliver the necessary materials for the cover system. The road weight limits could even increase the truck numbers. On-site heavy equipment operations would be necessary throughout this period. Indirect and direct impacts to the surrounding towns, including Norwich, Sharon, Strafford, and Thetford, would be observed through increased truck traffic, noise, dust, and road surface degradation. Soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect the amount of truck traffic. If a soil borrow pit is identified near the Site, truck traffic on local roads would be reduced if roads can be constructed through the woods from the Site to the soil borrow pit.

EPA will work with the local community to develop a traffic control plan that minimizes the impact of truck traffic to the extent practical.

4.4.3 Implementability (3B)

4.4.3.1 Technical Feasibility (3B)

Significant concerns with respect to the passive treatment system are: winter performance, the longevity of the treatment components, and the ability of the system to achieve water quality standards. Accomplishing the treatment of AMD through a passive or semi-passive system appears within reach of existing technologies. The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect, 99.98% removal efficiency for copper.

EPA’s expectation is that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. Data from pilot-scale treatability studies will be used to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal. EPA believes it is technically feasible to design a passive and/or semi-passive treatment system for the TP-3 contamination that has a reasonable probability of success. These issues must be addressed during the design.

The Alternative 3B cover is technically feasible. design and construction of the cover system (soil cover, diversion, and slope stability) uses proven and easily implemented technologies. It is technically feasible to design and construct a cover system that will meet the response objectives and EPA's technical guidance on final covers.

The ability to design, construct and operate a passive system to handle the anticipated flows is technically feasible. However, winter conditions in Vermont will impact the functionality of passive/natural treatment systems to some extent. Surface runoff that contacts TP-3 tailings is minimal through much of December, all of January/February, and much of March (25 to 30% of the year). Summer flow is generally very low to non-existent. Recent studies by Montana Tech (K. Burher, 2001, Personal Communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. Aerobic system functionality (polishing steps) may also be reduced due to thick ice cover and subsequent reduction in available oxygen. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged during winter months.

Such innovative passive/natural treatment systems would promote sustainable operations, biological diversity, and minimize operational and maintenance costs. The technology associated with the passive treatment system has been successfully implemented at a number of sites in the U.S. After the cap system and the diversion channels are constructed, the seepage at the toe of the combined tailings will be on the order of five gpm. For TP-3, the contaminated surface runoff and ground water seepage will have a high range of flow conditions. Preliminary design concepts call for a flow basis ranging from 20 to 40 gpm. The flow is to be handled by appropriate sizing of the passive treatment system and conservative sizing of the holding pond that will allow significant storage while treating at variable rates. The holding pond and passive treatment systems sizing allows for complete capture of runoff from a 100-year, 24-hour storm event.

During the winter months of December through mid-March, construction work is unlikely due to snow cover and frozen ground.

4.4.3.2 Administrative Feasibility (3B)

Alternative 3B is administratively feasible. Implementation of Alternative 3B will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation.

Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Coordination will be needed with the Vermont Department of Transportation and local community relative to traffic disruption and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Strafford, Sharon, Norwich, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the Town Select Board.

4.4.3.3 Availability of Services and Materials (3B)

Services and materials to implement alternative 3B are available. The excavation, transport, and regrading of tailings, and the construction of diversion channels and passive treatment systems will be performed using conventional construction equipment and techniques. Approximately 195,000 cubic yards of common borrow material, topsoil, aggregate, and limestone is required for this alternative. All of the material, except limestone, is available in sufficient quantities from many sources within 30 miles of the Site Local (i.e., Vermont/New Hampshire) contractors are available for earthmoving and construction activities.

Water is available from the WBOR at Tyson's Bridge, about 1½ miles from TP-1. Electric service is available at the main entrance to the Site. Commercial testing laboratories are readily available throughout New England.

4.4.3.4 State and Community Acceptance (3B)

EPA has actively involved the state and community in the alternatives identification process at the Elizabeth Mine Site. EPA, VTANR, and the EMCAG have been meeting regularly since April 2000. The formal evaluation of state and community acceptance will be addressed following VTANR, SHPO, and public review of this EE/CA.

Based on the past two years of discussion and meetings, EPA is providing this summary of "Concerns Expressed to Date": In February 2000, EPA held a public meeting to discuss a proposed early cleanup action at the Site. Many individuals in the community were concerned that the pace of the project, as proposed, would not provide the public with the level of involvement sought by the community. In response to these concerns, and a strong desire for local involvement, the communities of Strafford and Thetford formed the EMCAG to advise the EPA and ANR regarding community concerns related to the proposed cleanup. The EMCAG has been meeting since April 2000 and has taken an active role in cleanup discussions. The EE/CA Report, along with the previously released *Site Conditions Report*, *Historical Report*, *Alternatives Analysis Report*, and the *Preliminary Ecological and Human Health Risk Assessment Reports* are outcomes of the EPA and VTANR dialogue with the EMCAG. The reports provided the public with a substantial opportunity for early involvement in the assessment of the Site conditions, the nature of the hazards, the historic resources at the Site, and the identification of the cleanup alternatives that are evaluated in this EE/CA.

Since February 2000, the community expressed concerns regarding the total cost of the project, the historical significance of the Site, the time period required to design and implement a cleanup action, and the construction related truck traffic that would be required to transport the equipment and material to the Site. The following actions were undertaken in preparation of this EE/CA report to satisfy some of the community concerns:

- The costs included in this report reflect local vendor prices.
- Each alternative was designed to minimize impact to the historical resources of the Site.
- The volume of material used in each alternative represents as low a volume as practical to achieve the remedial action objectives; therefore, the truck numbers are considered the lowest possible.

State and Community acceptance will be further evaluated upon closure of the public comment period.

4.4.4 Cost (3B)

The capital costs and PRSC are summarized for each option in the following table. The cost breakdown and cost assumptions are provided in Appendix C.

Elizabeth Mine Cleanup Cost Table		
Cleanup Alternatives		**3B Soil Evapo-Transpiration Cover on TP-1 and TP-2**
Capital Costs	Option 1	$12,313,256
	Option 2	$13,837,778
	Option 3	$14,884,263
PRSC Activity	TP-1 Maintenance	$109,622
	TP-3 Maintenance (Option 1 - Complete Preservation of TP-3)	$254,359-$400,523
	TP-3 Maintenance (Option 2/3 – Preservation of 20% - 50% of TP-3)	$153,259-$200,940
Total Annual State Costs	Based on TP-1 and TP-3 Option 1	$364,021-$510,186
	Based on TP-1 and TP-3 Option 2/3	$262,922-$310,603

4.5 Alternative 3C

4.5.1 Description (3C)
Alternative 3C has the same objectives as Alternative 3B but seeks to minimize the soil cover to achieve the necessary level of protection. A six-inch topsoil cover over all of TP-1 and TP-2 is considered for this alternative. Reducing the soil cover thickness to six inches would significantly decrease the truck trips required for delivering the soil and other construction materials – from approximately 17,992 truck trips for the 42-inch ET cover to approximately 3,851 truck trips for the six-inch soil cover. This would significantly reduce the direct and indirect adverse effect on the surrounding towns and residents, including noise, dust, and road degradation. See Figure 3-5 for a conceptual drawing of Alternative 3C and Section 3 for a detailed description of Alternative 3C.

4.5.2 Effectiveness (3C)
The following sections provide the analysis of effectiveness for Alternative 3C.

4.5.2.1 Overall Protection of Human Health and the Environment (3C)
Alternative 3C achieves overall protection of human health and the environment by the following:

TP-3
For TP-3, overall protection of human health and the environment is accomplished through the collection of the discharge (run-off and groundwater) from the waste rock and heap leach piles of TP-3 and subsequent treatment of this water in a treatment

system. The passive treatment system will treat the collected water to meet VTWQS. The result will be a discharge to Copperas Brook and the WBOR that no longer has an adverse impact on these receiving waters. Since TP -3 will remain exposed, ongoing erosion must be an accepted condition of long-term performance if the historical integrity of the tailings is to be preserved. Some exposure to site contaminants would occur as a result of long-term human contact and wind blown transport of the waste rock and heap leach piles within TP-3. The concentration of metals found in TP-3, are not above levels that would warrant measures to prevent exposure to this material. Further studies of TP-3 will be performed during design to confirm that the material in TP-3 does not represent a threat to human health. Any waste rock or heap leach piles removed from TP-3 will be placed under the cover system for TP-1.

TP-1 and TP-2

For TP-1 and TP-2, overall protection of human health and the environment is accomplished through the covering of the exposed tailings, stabilization of the steep slopes, and reduction in the generation of AMD. The vegetated soil cover over the tailings will stabilize the tailings surface to minimize windblown transport of dust and minimize erosion. The filling of the decant pipes will further improve the stability of TP-1. The soil cover and perimeter diversion ditch will reduce the amount of water entering the TP-1 resulting in a dramatic reduction in AMD from TP-1. The residual flow from the seeps of TP-1 and TP-2 are expected to be approximately 22 gpm. The effluent of the passive treatment is expected to meet the discharge criteria, which will be based upon VTWQS.

4.5.2.2 Compliance With ARARs and Other Criteria, Advisories, and Guidance (3C)

Table 4-2 identifies the ARARs that apply to Alternative 3C. Alternative 3C would not comply with all federal and state location-, chemical-, and action-specific ARARs that apply to the Site. None of the alternatives comply with the current VTSWMR, however, the VTANR has issued a proposed rule change for public comment and has committed to finalizing the rule change such that the revised rule will be in effect prior to the signing of the EPA Action Memorandum. As a result, EPA has evaluated the VTSWMR based upon the assumed rule change. If the VTSWMR is not revised, then the EE/CA must be revised to assess ARAR compliance. Alternative 3C would not comply with the VTSWMR even as modified and is therefore not an ARAR compliant Alternative. As part of the ARAR evaluation, EPA is specifically seeking public comment on the following:

Unavoidable Impacts to Wetlands and Floodplain:

> The Wetlands below TP-1, on the surface of TP-1, adjacent to the adit, and within the stream channel of Copperas Brook from TP-3 to the outlet of TP-1 (Figure 1-9) as well as floodplain areas within Copperas Brook from TP-3 to the outlet of TP-1 will be impacted by the cleanup action. These impacts are unavoidable as there are no practicable alternatives to

the cleanup activities. The wetlands in these areas will be completely removed (destroyed). As a result, mitigation of the wetlands will be included in the design. Any floodplain impacts with be mitigated by designing a final surface water flow system that will have equal or better flood storage capacity. The cleanup action will also result in the dredging and filling of wetlands and waters of the U.S. Portions of Copperas Brook will be altered and re-located to separate Copperas Brook from the tailings. The re-location is unavoidable as the natural channel is beneath the tailings and removal of the two million cubic yards of tailings is considered impracticable.

Adverse Effect to a Historic Resource

Section 106 of the NHPA of 1966, as amended (16 USC 470f), requires EPA to take into account the effects of all actions on historic properties that have been determined to be eligible for the National Register of Historic Places. In order to be considered eligible, the site must meet at least one of four significance criteria and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, and in accordance with 36 CFR Part 60, the EPA has determined the Elizabeth Mine Site eligible for the National Register. The EPA has determined the site's significance to be best reflected by Criterion A: *those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Construction activities considered in this EE/CA will have direct and indirect impacts on features of the historic property at the Elizabeth Mine Site. EPA has determined that these impacts are unavoidable and necessary to protect human health and the environment. The preliminary APE for direct effects is shown in Figure 3-5. The APE will be further defined to address indirect effects, cumulative effects and other effects when a removal option is selected and the construction design is completed. EPA will work with the SHPO and other consulting parties to develop a MOA between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc (40 CFR 202, 203, 205), however, they are not considered ARARs for the purposes of this EE/CA.

VT Solid Waste Management Rules

Findings with respect to the VT Solid Waste Management Rules:

EPA has determined that certain requirements of the VTSWMR cannot be met in order to implement the cleanup action consistent with historic preservation and community concerns regarding truck traffic and cost. EPA is making the finding that alternative measures can be taken in implementing the remedy given that:

- The proposed alternative measures to the requirements of the VTSWMR will not endanger or tend to endanger human health or safety. The design, installation, and perpetual maintenance of measures to collect and treat all of the run-off from the portion of TP-3 that is retained for historic preservation purposes, would result in the protection of the aquatic resources of the WBOR as well as human health and safety with respect to the release of AMD at the Site. The alternative measures proposed for the final grade and slope cover systems for TP-1 and TP-2 would not endanger human health or safety since the cover system that will be implemented will have an equivalent level of protection as the cover system that was specified in the VTSWMR;

- Compliance with certain VTSWMR would produce serious hardship by causing the destruction of certain areas targeted for historic preservation without equal or greater benefit to the public. The alternative measures proposed for final grading and the slope cover system of TP-1 and TP-2 would have equal or greater benefit to public health and the environment while reducing the serious hardship to the historic resources at the Site. The alternative measure for the preservation of TP-3 would also have equal or greater benefit to public health and the environment while reducing the serious hardship to the historic resources at the Site;

- The material at the Site is not considered to be a hazardous waste subject to regulation under the Resource Conservation and Recovery Act (RCRA) Subtitle C; and

- There is no practicable means known or available to meet both the historic preservation requirements and certain requirements of the VTSWMR, however, the substitute or alternative measures proposed in this cleanup plan would achieve an equivalent level of protection of public health and the environment.

The specific alternative measures proposed to the particular requirements of the VTSWMR are detailed below:

- The design of the cleanup will determine the appropriate surface and slope grades at the Site as opposed to the minimum grade of 5% and the maximum grade of 33% specified in the VTSWMR. Performance objectives for the grading will be to:

minimize ponding on the barrier layer and promote run-off; minimize erosion; minimize AMD generation; and optimize slope steepness in the interest of historic preservation.

- Final closure of exposed waste rock and heap leach piles would not be required for TP-3. EPA would design and construct a collection and treatment system to address the run-off from TP-3. The change is dependent upon VTANR accepting the responsibility for the maintenance of the treatment system.

- Cleanup alternatives will not be required to include an infiltration barrier on the slopes of TP-1 or TP-2 if the design determines the infiltration barrier to be unnecessary to stabilize the slopes, minimize erosion, and minimize AMD generation.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc. (40 CFR 202, 203, 205); however, they are not considered ARARs for the purposes of this EE/CA.

4.5.2.3 Long-term Effectiveness and Permanence (3C)
Alternative 3C achieves long-term effectiveness and permanence by the following:

TP-3
The long-term effectiveness and permanence of the passive treatment systems is entirely dependent upon the implementation of the necessary long-term monitoring and maintenance activities. These systems if properly designed, constructed, monitored and maintained should function successfully for as long as they are needed. Compliance criteria should be met for as long as these systems are properly monitored and maintained.

TP-1 and TP-2
The long-term effectiveness and permanence of surface water diversion, soil cover, and passive treatment system for TP-1 and TP-2 is also dependent on monitoring and maintenance. However, the surface water diversions and soil cover can function effectively with minimal maintenance, whereas the passive treatment system is more maintenance dependent. For the area of TP-1 and TP-2, the soil cover will greatly reduce surface water infiltration into the tailings and the perimeter diversion channels will intercept shallow ground water flow into the tailings. The shallow soil cover will be susceptible to erosion and would require more rigorous inspection and maintenance activities than a cover of more substantial thickness. In addition, it is uncertain if vegetation can survive long-term with only six inches of soil as a buffer. Acid creep into the soil cover could have an impact on the vegetation. The estimated seepage quantity at the toe from infiltration through the combined tailings pile is estimated to be about 22 gpm. The seepage will be collected with a toe-drain and treated with the passive treatment system. The soil cover will also prevent exposure to the tailings, at least for

the short-term. The thin cover is likely to require repair periodically to ensure cover integrity.

4.5.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment (3C)

The passive treatment systems installed for treatment of the run-off from TP-3 and TP-1 and TP-2 will reduce the toxicity, mobility, and volume through treatment of contaminants by transforming soluble (and bioavailable) forms of metals into insoluble forms within the organic substrate. Passive treatment systems are designed to precipitate metal sulfides from solution through biologically-mediated reactions. Once in a sulfide form at near-neutral pH, copper and zinc (as examples) remain highly insoluble. Maintaining neutral pH is important in this substrate to retain the metals in sulfide form.

The surface water diversion and soil cover do accomplish a reduction in the volume of AMD and reduce the mobility of contaminants with the tailings, however, this benefit is achieved through containment, not treatment.

4.5.2.5 Short-Term Effectiveness (3C)

Alternative 3C achieves short-term effectiveness by the following:

TP-3

For TP-3, the improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. If funding for the NTCRA is available in 2002, the passive treatments systems could be installed in 2003 or 2004. Short-term impacts to floodplains, stream channels, and wetlands will be alleviated upon completion of the new stream channels and floodplain areas and restoration of the wetlands. Some short-term impacts to the community will occur from construction disturbances and truck traffic. The removal of the high metal-sulfide waste rock, if VTANR chooses TP-3 Options 2 or 3, would also have a direct positive effect by reducing the area of surface water contributing to the passive treatment systems, thereby reducing the long term loading to the passive treatment systems for TP-3.

TP-1 and TP-2

The reduction in erosion and dust will be evident immediately upon placement of the cap. The improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. In addition, a decrease in the volume of flow into the TP-1 and TP-2 passive treatment system should occur as a result of the soil cover. Alternative 3C does involve the moving and regrading of the tailings which will lead to the temporary exposure of fresh tailings over a wide area. The use of air monitoring and engineering controls, such as dust suppression and covering the tailings, will minimize any potential risks to nearby residents and the environment. Daily surface covers will be applied to reduce or eliminate exposure to the elements. Surface covers may include impervious tarps or a spray-on fixation compound. Such compounds have been tested at mining sites in the past with success, using locally available materials, such as power plant fly-ash and cement kiln dust. The design stage will fully evaluate options for construction safety needs.

Alternative 3C requires considerable truck traffic at various stages. Material movement from TP-2 to TP-1 would occur over a period of several months and require continuous truck traffic during working hours along a small portion of Mine Road, unless an alternate route is identified. Regrading of the tailings will involve considerable on-site truck and heavy machinery traffic over several months. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Construction of the proposed soil cover, diversion channels and passive treatment systems will require approximately 3,851 truck trips over a six-month period to deliver the necessary materials for the cover system. The road weight limits could even increase the truck numbers. On-site heavy equipment operations would be necessary throughout this period. Indirect and direct impacts to the surrounding towns, including Norwich, Sharon, Strafford, and Thetford, would be observed through increased truck traffic, noise, dust, and road surface degradation. Soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect the amount of truck traffic. If a soil borrow pit is identified near the Site, truck traffic on local roads would be reduced if roads can be constructed through the woods from the Site to the soil borrow pit.

EPA will work with the local community to develop a traffic control plan that minimizes the impact of truck traffic to the extent practical.

4.5.3 Implementability (3C)

4.5.3.1 Technical Feasibility (3C)

Significant concerns with respect to the passive treatment system are: winter performance, the longevity of the treatment components, and the ability of the system to achieve water quality standards. Accomplishing the treatment of AMD through a passive or semi-passive system appears within reach of existing technologies. The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for copper.

EPA's expectation is that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. Data from pilot-scale treatability studies will be used to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal. EPA believes it is technically feasible to design a passive and/or semi-passive treatment system for the TP-3 contamination that has a reasonable probability of success. These issues must be addressed during the design.

The cover design under Alternative 3C is technically feasible. Design and construction of the cover system (soil cover, diversion, and slope stability) uses proven and easily implemented technologies. It is technically feasible to design and construct a cover system that will meet the response objectives and EPA's technical guidance on final covers.

The ability to design, construct and operate a passive system to handle the anticipated flows is technically feasible. However, winter conditions in Vermont will impact the functionality of passive/natural treatment systems to some extent. Surface runoff that contacts TP-3 tailings is minimal through much of December, all of January/February, and much of March (25 to 30% of the year). Summer flow is generally very low to non-existent. Recent studies by Montana Tech (K. Burgher, 2001, Personal Communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. Aerobic system functionality (polishing steps) may also be reduced due to thick ice cover and subsequent reduction in available oxygen. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged during winter months.

Such innovative passive/natural treatment systems would promote sustainable operations, biological diversity, and minimize operational and maintenance costs. The technology associated with the passive treatment system has been successfully implemented at a number of sites in the U.S. After the cap system and the diversion channels are constructed, the seepage at the toe of the combined tailings will be on the order of -five gpm. For TP-3, the contaminated surface runoff and ground water seepage will have a high range of flow conditions. The flow is to be handled by appropriate sizing of the passive treatment systems and conservative sizing of the holding pond that will allow significant storage while treating at variable rates. The holding pond and the passive treatment systems sizing allows for complete capture of runoff from a 100-year, 24-hour storm event.

During the winter months of December through mid-March, construction work is unlikely due to snow cover and frozen ground.

4.5.3.2 Administrative Feasibility (3C)

Alternative 3C is administratively feasible. Implementation of Alternative 3C will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Coordination will be needed with the Vermont Department of Transportation and local community relative to traffic disruption and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Strafford, Sharon, Norwich, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the Town Select Board.

4.5.3.3 Availability of Services and Materials (3C)

Services and materials to implement Alternative 3C are available. The excavation, transport, and regrading of tailings, and the construction of diversion channels and passive treatment systems will be performed using conventional construction equipment and techniques. Approximately 28,000 cubic yards of common borrow material, topsoil, aggregate, and limestone are required for this alternative. All of the material is available in sufficient quantities from many sources within 30 miles of the Site. Local (i.e., Vermont/New Hampshire) contractors are available for earthmoving and construction activities.

Water is available from the WBOR at Tyson's Bridge, about 1½ miles from TP-1. Electric service is available at the main entrance to the Site. Commercial testing laboratories are readily available throughout New England.

4.5.3.4 State and Community Acceptance (3C)

EPA has actively involved the state and community in the alternatives identification process at the Elizabeth Mine Site. EPA, VTANR, and the EMCAG have been meeting regularly since April 2000. The formal evaluation of state and community acceptance will be addressed following VTANR, SHPO, and public review of this EE/CA.

Based on the past two years of discussion and meetings, EPA is providing this summary of "Concerns Expressed to Date": In February 2000, EPA held a public meeting to discuss a proposed early cleanup action at the Site. Many individuals in the community were concerned that the pace of the project, as proposed, would not provide the public with the level of involvement sought by the community. In response to these concerns, and a strong desire for local involvement, the communities of Strafford and Thetford formed the EMCAG to advise the EPA and ANR regarding community concerns related to the proposed cleanup. The EMCAG has been meeting since April 2000 and has taken an active role in cleanup discussions. The EE/CA Report, along with the previously released *Site Conditions Report*, *Historical Report*, *Alternatives Analysis Report*, and the *Preliminary Ecological and Human Health Risk Assessment Reports* are outcomes of the EPA and VTANR dialogue with the EMCAG. The reports provided the public with a substantial opportunity for early involvement in the assessment of the Site conditions, the nature of the hazards, the historic resources at the Site, and the identification of the cleanup alternatives that are evaluated in this EE/CA.

Since February 2000, the community expressed concerns regarding the total cost of the project, the historical significance of the Site, the time period required to design and implement a cleanup action, and the construction related truck traffic that would be required to transport the equipment and material to the Site. The following actions were undertaken in preparation of this EE/CA report to satisfy some of the community concerns:

- The costs included in this report reflect local vendor prices.
- Each alternative was designed to minimize impact to the historical resources of the Site.
- The volume of material used in each alternative represents as low a volume as practical to achieve the remedial action objectives; therefore, the truck numbers are considered the lowest possible.

State and Community acceptance will be further evaluated upon closure of the public comment period.

4.5.4 Cost (3C)

The capital costs and PRSC are summarized for each option in the following table. The cost breakdown and cost assumptions are provided in Appendix C.

Elizabeth Mine Cleanup Cost Table		
Cleanup Alternatives		**3C Six Inch Soil Cover on TP-1 and TP-2**
Capital Costs	Option 1	$9,414,895
	Option 2	$10,938,950
	Option 3	$11,985,902
PRSC Activity	TP-1 Maintenance	$131,918
	TP-3 Maintenance (Option 1 - Complete Preservation of TP-3)	$254-359-$400,523
	TP-3 Maintenance (Option 2/3 – Preservation of 20% - 50% of TP-3)	$153,259-$200,940
Total Annual State Costs	Based on TP-1 and TP-3 Option 1	$386,277-$532,441
	Based on TP-1 and TP-3 Option 2/3	$285,177-$332,859

4.6 Alternative 3D

4.6.1 Description (3D)

Alternative 3D has the same objectives as Alternatives 3B and 3C, but incorporates an induced chemical hardpan formation with a soil cover and drainage layer to minimize potential infiltration and support a grass covered surface.

Induced chemical hardpan capping is a technology that is currently being developed specifically for AMD generated by sulfide-rich tailings and waste rock. Hardpan capping relies on chemical reactions between sulfide waste rock and lime/limestone applied to a tailings pile's surface to create a hardpan layer or cap. The advantage of a chemical hardpan is that it would, in theory, require relatively low maintenance, as the cap is "self-healing," (i.e., when holes or cracks form in the cap and water enters, more capping material is formed by the chemical reaction)(Chermak and Runnells, 1996).

Induced chemical hardpans have certain drawbacks that must be fully evaluated prior to selection and implementation. Since this technology is relatively new to mine site remediation, there is little supporting literature to demonstrate the effectiveness of this approach. Although the concept involves a self-healing gypsum precipitation approach, it will be difficult to determine if the hardpan layer is uniformly reducing ground water infiltration. Studies to date have demonstrated a one-order-of-magnitude (10x) reduction in vertical permeability in one year in Norway using lime and limestone. Greater reductions would be necessary to be a cost-effective long-term approach for the Elizabeth Mine. The behavior of the hardpan in a climate similar to Vermont is in question, given the annual freeze-thaw cycles.

Given that this technology is in the development stage, there is a need for pilot scale testing to determine the effectiveness at the Elizabeth Mine. For Alternative 3D, the hardpan layer is covered by a drainage fabric, which is, in turn, covered by soil. Combined, this alternative offers two lines of defense against infiltration of water (ET cover with drainage layer, followed by the hardpan cap).

Surface drainage would follow the original surface flow patterns across the tailings and clean storm-water would be collected and discharged through the perimeter diversion channels without impacting any other features of historic importance. TP-3 contaminated surface water and seepage will be treated as in Alternative 3C. A toe drain will be installed to collect the seepage at the toe of TP-1 and TP-2. The collected water will be treated with the passive/natural treatment system. See Figure 3-6 for a conceptual drawing of Alternative 3D and Section 3 for a detailed description of Alternative 3D.

4.6.2 Effectiveness (3D)

The following sections provide an analysis of the effectiveness of Alternative 3D.

4.6.2.1 Overall Protection of Human Health and the Environment (3D)
Alternative 3D achieves overall protection of human health and the environment by the following:

TP-3
For TP-3, overall protection of human health and the environment is accomplished through the collection of the discharge (run-off and groundwater) from the waste rock and heap leach piles of TP-3 and subsequent treatment of this water in a treatment system. The passive treatment system will treat the collected water to meet VTWQS. The result will be a discharge to Copperas Brook and the WBOR that no longer has an adverse impact on these receiving waters. As TP -3 will remain exposed, ongoing erosion must be an accepted condition of long-term performance if the historical integrity of the tailings is to be preserved. Some exposure to site contaminants would occur as a result of long-term human contact and wind blown transport of the waste rock and heap leach piles within TP-3. The concentration of metals found in TP-3, are not above levels that would warrant measures to prevent exposure to this material. Further studies of TP-3 will be performed during design to confirm that the material in TP-3 does not represent a threat to human health. Any waste rock and heap leach piles removed from TP-3 will be placed under the cover system for TP-1. This material will no longer be a source for AMD.

TP-1 and TP-2
For TP-1 and TP-2, overall protection of human health and the environment is accomplished through the covering of the exposed tailings, stabilization of the steep slopes, and reduction in the generation of AMD. The hardpan cap/soil cover over the tailings will effectively stabilize the tailings surface to prevent windblown transport of dust and minimize erosion. The filling of the decant pipes will further improve the stability of TP-1. The soil cover and perimeter diversion ditch will effectively minimize the amount of water entering the TP-1 resulting in a dramatic reduction in AMD from TP-1. The residual flow from the seeps of TP-1 and TP-2 are expected to be approximately 8 gpm. The effluent of the passive treatment is expected to meet the discharge criteria, which will be based upon VTWQS.

4.6.2.2 Compliance With ARARs and Other Criteria, Advisories, and Guidance (3D)
Table 4-2 identifies the ARARs that apply to Alternative 3D. Alternative 3D would comply with all federal and state location-, chemical-, and action-specific ARARs that apply to the Site. This compliance determination is dependent upon the final implementation of a rule change to the VTSWMR). None of the alternatives comply with the current VTSWMR, however, the VTANR has issued a proposed rule change for public comment and has committed to finalizing the rule change such that the revised rule will be in effect prior to the signing of the EPA Action Memorandum. As a result, EPA has evaluated the VTSWMR based upon the assumed rule change. If the VTSWMR is not revised, then the EE/CA must be revised to assess ARAR compliance. Alternative 3D would only comply with the revised VTSWMR is the hard pan layer is

considered to be equivalent to the barrier layer required for the non-slope areas of TP-1 and TP-2. As part of the ARAR evaluation, EPA is specifically seeking public comment on the following:

Unavoidable Impacts to Wetlands and Floodplain:

The Wetlands below TP-1, on the surface of TP-1, adjacent to the adit, and within the stream channel of Copperas Brook from TP-3 to the outlet of TP-1 (Figure 1-9) as well as floodplain areas within Copperas Brook from TP-3 to the outlet of TP-1 will be impacted by the cleanup action. These impacts are unavoidable as there are no practicable alternatives to the cleanup activities. The wetlands in these areas will be completely removed (destroyed). As a result, mitigation of the wetlands will be included in the design. Any floodplain impacts with be mitigated by designing a final surface water flow system that will have equal or better flood storage capacity. The cleanup action will also result in the dredging and filling of wetlands and waters of the U.S. Portions of Copperas Brook will be altered and re-located to separate Copperas Brook from the tailings. The re-location is unavoidable as the natural channel is beneath the tailings and removal of the two million cubic yards of tailings is considered impracticable.

Adverse Effect to a Historic Resource

Section 106 of the NHPA of 1966, as amended (16 USC 470f), requires EPA to take into account the effects of all actions on historic properties that have been determined to be eligible for the National Register of Historic Places. In order to be considered eligible, the site must meet at least one of four significance criteria and possess integrity among some of the following qualities: original location, design, setting, workmanship, materials, or feelings and association. In consultation with the SHPO, and in accordance with 36 CFR Part 60, the EPA has determined the Elizabeth Mine Site eligible for the National Register. The EPA has determined the site's significance to be best reflected by Criterion A: *those sites that are associated with events that have made a significant contribution to the broad patterns of our history;* and Criterion D: *those sites that have yielded, or may be likely to yield, information important in prehistory or history*. Construction activities considered in this EE/CA will have direct and indirect impacts on features of the historic property at the Elizabeth Mine Site. EPA has determined that these impacts are unavoidable and necessary to protect human health and the environment. The preliminary APE for direct effects is shown in Figure 3-6. The APE will be further defined to address indirect effects, cumulative effects and other effects when a removal option is selected and the construction design is completed. EPA will work with the SHPO and other consulting parties to develop a MOA between the EPA, the SHPO, and other appropriate consulting parties to address any adverse effects to historic properties.

VT Solid Waste Management Rules

Findings with respect to the VT Solid Waste Management Rules:

EPA has determined that certain requirements of the VTSWMR cannot be met in order to implement the cleanup action consistent with historic preservation and community concerns regarding truck traffic and cost. EPA is making the finding that alternative measures can be taken in implementing the remedy given that:

- The proposed alternative measures to the requirements of the VTSWMR will not endanger or tend to endanger human health or safety. The design, installation, and perpetual maintenance of measures to collect and treat all of the run-off from the portion of TP-3 that is retained for historic preservation purposes, would result in the protection of the aquatic resources of the WBOR as well as human health and safety with respect to the release of AMD at the Site. The alternative measures proposed for the final grade and slope cover systems for TP-1 and TP-2 would not endanger human health or safety since the cover system that will be implemented will have an equivalent level of protection as the cover system that was specified in the VTSWMR;

- Compliance with certain VTSWMR would produce serious hardship by causing the destruction of certain areas targeted for historic preservation without equal or greater benefit to the public. The alternative measures proposed for final grading and the slope cover system of TP-1 and TP-2 would have equal or greater benefit to public health and the environment while reducing the serious hardship to the historic resources at the Site. The alternative measure for the preservation of TP-3 would also have equal or greater benefit to public health and the environment while reducing the serious hardship to the historic resources at the Site;

- The material at the Site is not considered to be a hazardous waste subject to regulation under the Resource Conservation and Recovery Act (RCRA) Subtitle C; and

- There is no practicable means known or available to meet both the historic preservation requirements and certain requirements of the VTSWMR, however, the substitute or alternative measures proposed in this cleanup plan would achieve an equivalent level of protection of public health and the environment.

The specific alternative measures proposed to the particular requirements of the VT SWMR are detailed below:

- The design of the cleanup will determine the appropriate surface and slope grades at the Site as opposed to the minimum grade of 5% and the maximum grade of 33% specified in the VTSWMR. Performance objectives for the grading will be to: minimize ponding on the barrier layer and promote run-off; minimize erosion; minimize AMD generation; and optimize slope steepness in the interest of historic preservation.

- Final closure of exposed waste rock and heap leach piles would not be required for TP-3. EPA would design and construct a collection and treatment system to address the run-off from TP-3. The change is dependent upon VTANR accepting the responsibility for the maintenance of the treatment system.

- Cleanup alternatives will not be required to include an infiltration barrier on the slopes of TP-1 or TP-2 if the design determines the infiltration barrier to be unnecessary to stabilize the slopes, minimize erosion, and minimize AMD generation.

All offsite construction-related operations will comply with offsite rules regarding traffic, permits, restrictions, etc. (40 CFR 202, 203, 205); however, they are not considered ARARs for the purposes of this EE/CA.

4.6.2.3 Long-term Effectiveness and Permanence (3D)
Alternative 3D achieves long-term effectiveness and permanence by the following:

TP-3

The long-term effectiveness and permanence of the passive treatment systems is entirely dependent upon the implementation of the necessary long-term monitoring and maintenance activities. These systems if properly designed, constructed, monitored and maintained should function successfully for as long as they are needed. Compliance criteria should be met for as long as these systems are properly monitored and maintained.

TP-1 and TP-2

The long-term effectiveness and permanence of surface water diversion, hardpan cap/soil cover, and passive treatment system for TP-1 and TP-2 is also dependent on monitoring and maintenance. However, the surface water diversions and hardpan cap/soil cover can, in theory, function effectively with minimal maintenance, whereas the passive treatment system is more maintenance dependent. For the area of TP-1 and TP-2, the hardpan cap system will reduce surface water and oxygen infiltration into the tailings and the perimeter diversion channels will intercept shallow ground water flow into the tailings. The estimated seepage quantity at the toe of the combined tailings pile from infiltration sources is estimated to be about 8 gpm. The seepage will be collected with a toe-drain and treated with the passive treatment system. The soil cover will also effectively prevent exposure to the tailings. The long-term effectiveness of the hardpan cap has not been proven, due to limited use of this technology.

4.6.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment (3D)

The passive treatment systems installed for treatment of the run-off from TP-3 and TP-1/TP-2 will reduce the toxicity, mobility, and volume through treatment of contaminants by transforming soluble (and bioavailable) forms of metals into insoluble forms within the organic substrate. Passive Treatment systems are designed to precipitate metal sulfides from solution through biologically-mediated reactions. Once in a sulfide form at near-neutral pH, copper and zinc (as examples) remain highly insoluble. Maintaining neutral pH is important in this substrate to retain the metals in sulfide form.

The surface water diversion and hardpan cap do accomplish a reduction in the volume of AMD and reduce the mobility of contaminants with the tailings, however, this benefit is achieved through containment, not treatment.

4.6.2.5 Short-Term Effectiveness (3D)

Alternative 3D achieves short-term effectiveness by the following:

TP-3

For TP-3, the improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. If funding for the NTCRA is available in 2002, the passive treatment systems could be installed by 2003 or 2004. Short-term impacts to floodplains, stream channels, and wetlands will be alleviated upon completion of the new stream channels and floodplain areas and restoration of the wetlands. Some short-term impacts to the community will occur from construction disturbances and truck traffic. The removal of the high metal-sulfide waste rock, if VTANR chooses TP-3 Options 2 or 3, would also have a direct positive effect by reducing the area of surface water contributing to the passive treatment systems, thereby reducing the long term loading to the passive treatment systems for TP-3.

TP-1 and TP-2

The reduction in erosion and dust will be evident immediately upon placement of the cap. The improvement in the water quality of Copperas Brook and WBOR will begin once the passive treatment systems are operational. In addition, a decrease in the volume of flow into the TP-1 and TP-2 passive treatment system should occur within five years of the diversion ditch and hardpan cap/soil cover installation being complete. Alternative 3D does involve substantial moving and regrading of the tailings which will lead to the temporary exposure of fresh tailings over a wide area. The use of air monitoring and engineering controls, such as dust suppression and covering the tailings, will minimize any potential risks to nearby residents and the environment. Daily surface covers will be applied to reduce or eliminate exposure to the elements. Surface covers may include impervious tarps or a spray-on fixation compound. Such compounds have been tested at mining sites in the past with success, using locally available materials, such as power plant fly ash and cement kiln dust. The design stage will fully evaluate options for construction safety needs.

Alternative 3D requires considerable truck traffic at various stages. Material movement from TP-2 to TP-1 would occur over a period of several months and require continuous truck traffic during working hours along a small portion of Mine Road, unless an alternate route is identified. Regrading of the tailings will involve considerable on-site truck and heavy machinery traffic over several months. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Construction of the proposed soil cover, diversion channels and passive treatment systems will require approximately 9,287 truck trips over a six-month period to deliver the necessary materials for the cover system. The road weight limits could even increase the truck numbers. On-site heavy equipment operations would be necessary throughout this period. Indirect and direct impacts to the surrounding towns, including Norwich, Sharon, Strafford, and Thetford, would be observed through increased truck traffic, noise, dust, and road surface degradation. Soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect the amount of truck traffic. If a soil borrow pit is identified near the Site, truck traffic on local roads would be reduced if roads can be constructed through the woods from the Site to the soil borrow pit.

EPA will work with the local community to develop a traffic control plan that minimizes the impact of truck traffic to the extent practical.

4.6.3 Implementability (3D)

4.6.3.1 Technical Feasibility (3D)

Significant concerns with respect to the passive treatment system are: winter performance, the longevity of the treatment components, and the ability of the system to achieve water quality standards. Accomplishing the treatment of AMD through a passive or semi-passive system appears within reach of existing technologies. The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for copper.

EPA's expectation is that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. Data from pilot-scale treatability studies will be used to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal. EPA believes it is technically feasible to design a passive and/or semi-passive treatment system for the TP-3 contamination that has a reasonable probability of success. These issues must be addressed during the design.

Design and construction of the Alternative 3D hardpan cap/soil cover system (soil cover, diversion, and slope stability) uses proven and easily implemented technologies. It is technically feasible to design and construct a hardpan cap/soil cover system that will meet the response objectives and EPA's technical guidance on final covers.

The ability to design, construct and operate a passive system to handle the anticipated flows is technically feasible. However, winter conditions in Vermont will impact the functionality of passive/natural treatment systems to some extent. Surface runoff that contacts TP-3 tailings is minimal through much of December, all of January/February, and much of March (25 to 30% of the year). Summer flow is generally very low to non-existent. Recent studies by Montana Tech (K. Burgher, 2001, Personal Communication, and ICARD, 2000) indicate that severe winter conditions impact functionality through reduced microbial action and restrictions in flow volume, due to ice cover. Aerobic system functionality (polishing steps) may also be reduced due to thick ice cover and subsequent reduction in available oxygen. At an AMD test site in Montana, zinc removal rates in a constructed wetland were slightly impacted, but copper removal efficiency remained unchanged during winter months. Such innovative passive/natural treatment systems would promote sustainable operations, biological diversity, and minimize operational and maintenance costs. The technology associated with the passive treatment system has been successfully implemented at a number of sites in the U.S. For TP-3, the contaminated surface runoff and ground water seepage will have a high range of flow conditions. The flow is to be handled by appropriate sizing of passive treatment systems and conservative sizing of the holding pond that will allow significant storage while treating at variable rates. The holding pond and passive treatment systems sizing allows for complete capture of runoff from a 100-year, 24-hour storm event.

During the winter months of December through mid-March, construction work is unlikely, due to snow cover and frozen ground.

4.6.3.2 Administrative Feasibility (3D)
Alternative 3D is administratively feasible. Implementation of Alternative 3D will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate federal, state, and local agencies will be required to implement this alternative. Construction involves direct impacts to both the town and the local residents through truck traffic, noise, and dust. Coordination will be needed with the Vermont Department of Transportation and local community relative to traffic disruption and road use. Coordination will also be needed with local companies regarding water and electricity supply.

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4.6.3.3 Availability of Services and Materials (3D)

Services and materials to implement Alternative 3D are available. The excavation, transport, and regrading of tailings, and the construction of diversion channels and passive treatment systems will be performed using conventional construction equipment and techniques. Approximately 110,000 cubic yards of common borrow material, topsoil, aggregate, and limestone are required for this alternative. All of the material, except limestone, is available in sufficient quantities from many sources within 30 miles of the Site. Local (i.e., Vermont/New Hampshire) contractors are available for earthmoving and construction activities.

Water is available from the WBOR at Tyson’s Bridge, about 1½ miles from TP-1. Electric service is available at the main entrance to the Site. Commercial testing laboratories are readily available throughout New England.

4.6.3.4 State and Community Acceptance (3D)

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Since February 2000, the community expressed concerns regarding the total cost of the project, the historical significance of the Site, the time period required to design and implement a cleanup action, and the construction related truck traffic that would be required to transport the equipment and material to the Site. The following actions were undertaken in preparation of this EE/CA report to satisfy some of the community concerns:

- The costs included in this report reflect local vendor prices.
- Each alternative was designed to minimize impact to the historical resources of the Site.
- The volume of material used in each alternative represents as low a volume as practical to achieve the remedial action objectives; therefore, the truck numbers are considered the lowest possible.

State and Community acceptance will be further evaluated upon closure of the public comment period.

4.6.4 Cost (3D)

The capital costs and PRSC are summarized for each option in the following table. The cost breakdown and cost assumptions are provided in Appendix C.

Elizabeth Mine Cleanup Cost Table		
Cleanup Alternatives		**3D Chemical Cap (Hardpan) with Soil Cover on TP-1 and TP-2**
Capital Costs	Option 1	$12,040,253
	Option 2	$13,564,308
	Option 3	$14,611,260
PRSC Activity	TP-1 Maintenance	$90,276
	TP-3 Maintenance (Option 1 - Complete Preservation of TP-3)	$254,359-$400,523
	TP-3 Maintenance (Option 2/3 – Preservation of 20% - 50% of TP-3)	$153,259-$200,940
Total Annual State Costs	Based on TP-1 and TP-3 Option 1	$344,635-$490,799
	Based on TP-1 and TP-3 Option 2/3	$243,535-$291,216

5.0 Comparative Analysis of Removal Action Alternatives

This section of the EE/CA provides a comparison of the five alternatives described in Section 4.0. Figure 5-1 presents a summary of the cover systems for the five alternatives. The relative advantages and disadvantages of each alternative are discussed with respect to the following criteria:

1. Effectiveness
   -Overall protection of human health and the environment
   -Compliance with ARARs and other criteria, advisories, and guidance
   -Long-term effectiveness and permanence
   -Reduction in toxicity, mobility, or volume through treatment
   -Short-term effectiveness

2. Implementability
   -Technical feasibility
   -Administrative feasibility
   -Availability of services and materials
   -State and community acceptance

3. Cost

The Cost criterion includes both direct and indirect capital costs. The State and Community Acceptance criteria will be modified following the public comment period to reflect issues and concerns that arise through discussions with the EMCAG and the public.

5.1 Effectiveness

5.1.1 Overall Protection of Human Health and the Environment.

The five alternatives all offer similar levels of protection of human health and the environment. For TP-3, each alternative has identical performance. For TP-1 and TP-2, the major differences are as follows:

- The thin soil cover component of Alternative 3C is more likely to allow exposure of the tailings as a result of erosion than the covers described for alternatives 2B, 2C, 3B, and 3D.
- The thin soil cover component of Alternative 3C may not be able to sustain a vegetated cover due to acid creep.
- The long-term effectiveness of the Alternative 3D hardpan cap is not known.
- Alternatives 2B and 2C would result in the least amount of infiltration into the tailings of TP-1 and TP-2. Alternatives 3B and 3D would greatly reduce infiltration

while Alternative 3C would have the lowest level of infiltration reduction (allow the greatest amount of water into the tailings).

The geomembrane cap that is a component of Alternatives 2B and 2C has a proven record of performance. The cover system included in Alternatives 2B and 2C is a tiered system that significantly limits the infiltration of water and oxygen into the tailings. First, the cover system would be designed to have a final surface grade to promote run-off as opposed to allowing infiltration. Second, the natural soil and vegetation component of the cover stores water that is then recycled into the atmosphere through the process of evaporation and transpiration. Third, the drainage layer within the cover provides a high capacity system for removing water that may flow past the first two components. This water is channeled to outlets in the cover system to prevent any long-term storage of water above the geomembrane. Fourth, a geomembrane prevents further water and oxygen migration by acting as seal or barrier to water and airflow. The geomembrane is a continuous sheet of plastic that essentially prevents water from seeping into the tailings. Finally, if determined necessary to assure long-term performance beyond the life expectancy of a geomembrane (could be hundreds of years), a second barrier of a natural material can be included to seal any holes or cracks that may develop in the geomembrane over time. This secondary layer would further prevent the inflow of water and oxygen into the tailings. Either a low permeability soil layer or a geosynthetic clay liner can be used as the second barrier layer. This system of natural and engineering components should eliminate all infiltration of water and oxygen into the tailings from the surface.

The soil cover components of Alternatives 3B, 3C, and 3D also perform the first two functions (surface water drainage and evapotranspiration) described above. Alternative 3C does not have any additional measures to reduce surface infiltration, whereas, Alternative 3D includes the drainage layer component and a single barrier layer (hardpan) to further limit infiltration. Alternative 3B attempts to maximize the use of natural soil properties (storage and evapotranspiration) by increasing the thickness of the soil layer, as opposed to installing a barrier layer. The other aspects of these alternatives, relative to overall protection of human health and the environment, are the same.

5.1.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

All alternatives will have the same level of impact to wetlands, stream channels, and floodplains. These impacts are unavoidable and will be subject to mitigation. Alternatives 3C and 3D would not comply with the performance standards for an infiltration barrier layer over the non-slope portion of TP-1 and TP-2 as specified in sections of the VTSWMR that are subject to the variance or waiver as described in this EE/CA. Alternative 3B would only comply with this ARAR if the bottom 18 inches of soil in the cover were installed with a permeability of 1 x 10^{-5} cm/sec or less. As a result, only the cover systems described in Alternatives 2B, 2C, and 3B would comply with the VTSWMR.

All alternatives under consideration in this EE/CA involve impacts to historic resources that are eligible for the National Register of Historic Places. Each of the alternatives considered in this report seeks to minimize the impact of the cleanup on the historic resources at the Site. All three tailings piles possess value as historic landscapes. The most immediate and visible historic resources at the Elizabeth Mine are the major landscape elements left from the copperas and copper production activities in the form of tailings or waste rock piles.

Many of the historic components, such as TP-3, are known or potential archaeological resources that have the potential to yield information about industrial and technological activities spanning almost 160 years. TP-3 has been identified as the location of the nineteenth-century copperas production and, therefore, possesses high historic value, as an archaeological site for its potential to contain information about this poorly understood early industrial process. Although there is potential for archaeological remains of late nineteenth and early twentieth-century industrial activity under TP-1 and TP-2, those resources have already been impacted by burial under tailings materials that are not slated for removal. There may be some archaeological testing required in areas slated for associated response activity, such as transportation routes or grading activities, particularly at the west edges of TP-1 and TP-2. The major impact to historic resources associated with TP-1 and TP-2 will be impacts to their appearance and value as major historic landscape elements.

From a historic preservation standpoint, the best response alternatives for resources of archaeological value are those that avoid disturbance to archaeologically sensitive areas, or that combine site avoidance with an archaeological data recovery component for those areas that cannot be avoided. The best response action alternatives for resources of visual landscape value are those that retain and/or recreate the basic formal elements of the historic resource, including size, mass, shape, geometry, color, and texture. Retention of these areas and qualities also offers a highly advantageous result in terms of future uses for the mine.

The adverse effects of the cleanup on the historic resource include covering or capping TP-1 and TP-2, altering the visual landscape through the addition of the surface water channels and passive treatment systems and the physical removal of portions of TP-3. During design of the selected Alternative, EPA will attempt to maintain a surface topography that retains (to the extent practicable and ARAR compliant) the steep slopes and large plateaus of TP-1 and TP-2, however, the color, texture, and ability to directly observe the tailings will be lost. The top surface TP-1 and TP-2 will be grass or rock-covered and the steep, eroded slopes observed today, will become a sloped grass or rock cover. Alternative 2B will result in a more substantial impact to the tailing profile as a result of the excavation of TP-2 and the consolidation of this material onto TP-1.

EPA has indicated an intention to preserve as much of TP-3 as possible and to minimize direct impacts to the copperas works and Tyson-era features. The critical factor in TP-3 preservation is the amount of maintenance that the State of Vermont is willing to accept. At this time the State of Vermont has expressed a preference for Option 1 (complete preservation) provided funding is available to support this position. Upon completion of the design, EPA will provide a revised estimate of the PRSC costs associated with TP-3 and request that the State of Vermont finalize the decision with respect to TP-3. It is not possible to anticipate the effects of the remediation upon the entire historic property until an alternative is selected and the construction proposal is in the design stage. At that point, consultation with the SHPO and the other consulting parties will continue to identify impacts and address any additional adverse effects that may be identified. The resolution to the adverse effects will be the outcome of the consultation and will be embodied in the stipulations in the MOA

5.1.3 Long-Term Effectiveness and Permanence

The five alternatives all provide the same level of long-term effectiveness and permanence with respect to TP-3. The long-term effectiveness and permanence with respect to the treatment of the exposed material remaining at TP-3 is entirely dependent upon the successful design and construction of these innovative treatment systems along with the maintenance (PRSC) of these systems by the State of Vermont. Failure to maintain the passive treatment system would allow the AMD to enter the surface water of Copperas Brook with subsequent impacts to the ecological receptors.

Alternatives 2B and 2C have the highest level of long-term effectiveness and permanence. Alternative 3D may approach the long-term effectiveness and permanence of 2B and 2C if the hardpan is truly uniform, self-healing, and of low permeability. However, re-application of the limestone may be necessary to maintain the effectiveness of the hardpan. Alternative 3B has a somewhat lower level of effectiveness, because it allows greater infiltration of water and oxygen into the tailings. Alternative 3C has the lowest level of effectiveness and permanence, given the thin cover and potential for disturbance and erosion. Alternative 3C is likely to continue to allow significant surface water infiltration and oxygen into the tailings, for the following reasons:

- Considering construction accuracy, the soil cover may be less than six inches in some places and more than six inches in others.
- Cyclic wet/dry conditions and frost/melt events will result in non-uniform infiltration.
- Six inches of soil is insufficient to maintain a healthy, sustainable vegetative cover

5.1.4 Reduction in Toxicity, Mobility, or Volume through Treatment

Caps and covers are not considered treatment. However, treatment to reduce the mobility of the contamination will occur in the passive treatment systems. These systems will effectively neutralize the low pH run-off and cause the precipitation and sequestering of the metals within the run-off. The treatment process and effectiveness is largely the same for all five alternatives, therefore, reduction in toxicity, mobility, or volume through treatment is not a distinguishing factor between alternatives, except that the amount of water treated will vary.

5.1.5 Short-term Effectiveness

Short-term effectiveness includes an assessment of the time period until the removal action goals are met. All alternatives should be able to meet these goals shortly after construction is complete. Once the passive treatment systems are fully operational (within 2-3 years of construction), the AMD impacts to Copperas Brook and the WBOR should be eliminated. The cover system for Alternatives 2B, 2C, 3B, and 3C and diversion ditches included in all Alternatives will have the immediate effect of reducing the amount of clean water coming into contact with the tailings and a long-term effect of reducing the flow to the passive treatment system for TP-1.

Short-term effectiveness also considers the magnitude of potential threats to the community, Site workers, and the environment during implementation of a response action. This includes threats that result from implementing the remedy itself as well as existing threats that persist until mitigated by the cleanup action.

All alternatives have a potential for exposure of fresh sulfide material to storm events, since some unoxidized tailings are likely to be exposed to achieve final grades or consolidate a portion of TP-2. The design will focus on a final slope configuration that minimizes the exposure of unoxidized tailings. Each alternative involves substantial construction-related activity and truck traffic. Tailings movement from TP-2 to TP-1 and TP-3 to TP-1 is likely to occur over a several month period and require continuous truck traffic during working hours along a small portion of Mine Road unless an alternate route is identified. This activity should not result in a direct impact to the village of South Strafford; however local residents in the Mine Road area would be directly impacted. However, at this time, EPA must assume that all of the materials required to construct the cover systems will be brought to the Site from an off-site location. EPA will attempt to locate and reach agreement with adjacent landowner regarding the use of locally available soil material to reduce truck traffic. The estimated trucks required for delivering construction materials for each alternative are shown in the following table:

Alternative	Estimated Truck Count For Cap/Cover,[1,2] (Round Trips)
Alternative 2B	7,765
Alternative 2C	7,765
Alternative 3B	17,992
Alternative 3C	3,851
Alternative 3D	9,287

1. A two season construction period has been estimated,
2. Estimations based on 12 cubic yard truck volume.

The surrounding towns, including Norwich, Sharon, Strafford, and Thetford, may be affected by increased truck traffic, noise, dust, and road surface degradation. Road weight limits, soil stockpile strategies, location of soil for the soil cover component, and the length of the construction season will affect truck traffic volume. If a soil borrow pit is identified near the Site, traffic impacts may be reduced to a small area especially if roads can be constructed through the woods from the Site to the soil borrow pit.

Potential risks to Site workers arise from performing construction activities and from exposure to contaminants in tailings, soil, groundwater, and air. Potential risks will be controlled by development and adherence to a site-specific Health and Safety Plan.

5.2 Implementability

5.2.1 Technical Feasibility

It is technically feasible to implement each of the five alternatives. Design and construction of the cap/soil cover system and the surface water diversion channels use proven and easily implemented technologies. For all alternatives, the tailings slopes will be stabilized using some combination of slope re-grading, rip rap, or buttressing. All of these techniques have been used in construction and slope rehabilitation of many tailing piles and landfills.

It is technically feasible to build the passive/natural treatment system for all alternatives. There are some concerns with respect to the ability of the passive treatment technology to achieve water quality criteria for all constituents for TP-3 as well as the cold weather performance of these systems.

Accepting the objective that the cleanup be a community-based solution, with strong support from the State of Vermont, this EE/CA has been developed based upon the State of Vermont's and local community's preference for leaving as much of TP-3 in place as possible. This objective is based upon the historic value of TP-3. This goal is achievable, but requires a level of engineering and scientific ingenuity that goes beyond more conventional remediation approaches. Leaving TP-3 in place also introduces additional operation and maintenance activities, and their corresponding costs, in-perpetuity. EPA is prepared to undertake, with an expectation of success, the challenge of designing a remediation alternative that considers leaving TP-3 in place.

Leaving TP-3 in place requires a waiver of the Vermont Solid Waste regulations relative to slope and cover requirements. The current regulations require that TP-3 be flattened to a slope much less steep that the current slope configuration and also requires that all waste material be covered with a low permeability cover system. Assuming the State waives these requirements, accomplishing the treatment of AMD through a passive or semi-passive system appears within reach of existing technologies.

The treatment system for TP-3 must meet Vermont water quality discharge criteria on a sustained basis for all metals. This means achieving a nearly perfect 99.98% removal efficiency for copper.

EPA expects that it is possible to design a system based on technologies proven to work at other locations, although the design of this system will push the performance envelope of these technologies. EPA will undertake bench and pilot-scale treatability studies to refine the conceptual treatment scheme into a detailed design. Leaving TP-3 in place results in a higher level of uncertainty when compared with an approach based on partial or full source removal.

Since the passive treatment systems are the same for each Alternative, technical feasibility of these systems is not a strong distinguishing factor among alternatives.

5.2.2 Administrative Feasibility

Implementation of any of the alternatives in this EE/CA will result in costs exceeding the NTCRA $2 million and 12-month statutory limit. Therefore, an exemption from these statutory requirements will be required prior to implementation. Because the type of action and basis for action are consistent with any action that may be taken under a long-term remedial program, a consistency waiver is appropriate for each of the alternatives.

Coordination with appropriate state and local agencies will be required to implement any of the alternatives. Construction involves direct and indirect impacts to both the town and the local residents through truck traffic, noise, and dust. EPA will coordinate with the Vermont Agency of Transportation, town Select Boards and the local community regarding traffic impacts and road use. Coordination will also be needed with local companies regarding water and electricity supply.

Overweight vehicle permits must be obtained for vehicles greater than 12 tons in Norwich, Strafford, Sharon, and Thetford, Vermont. Prior to construction of additional access roads to the Site, Highway Access Permits (Strafford) and Driveway Permits (Thetford) must be obtained from the town Select Boards.

Administrative feasibility is not, therefore, a strong distinguishing factor among alternatives.

5.2.3 Availability of Services and Materials

The differences between alternatives are largely related to cap and cover construction materials and the necessary service expertise for installation/construction. Common borrow material and topsoil are needed for each of the alternatives. Crushed limestone is needed for passive treatment systems in each alternative and the hardpan cover (3D). Availability of services and materials should not be a constraint for any of the alternatives under consideration. On the basis of this criterion, none of the five alternatives are more or less desirable.

5.2.4 State and Community Acceptance

State and community acceptance will be addressed through the public comment process. EPA has worked closely with the State of Vermont and local communities to develop the short list of alternative response actions represented in this EE/CA. Throughout this process the community has clearly articulated their concerns and desires. The state has been involved in all aspects of the planning and community outreach process.

Community concerns include the following:

- Effectiveness of the cleanup
- Preservation (to the extent practicable) of Site elements with historic/cultural value
- Limiting truck traffic and construction impacts to the community
- Scale and cost of the cleanup
- Innovation, re-use, and education

Effectiveness of the Cleanup. The alternatives can be distinguished on the basis of Effectiveness of the Cleanup. Alternatives 2B and 2C will be most effective at reducing AMD over the long-term, while Alternative 3C will be the least effective. Uncertainties remain concerning the effectiveness of an induced hardpan layer in Alternative 3D. The long-term maintenance of the passive treatment systems is the most critical element of effectiveness for the treatment of the TP-3 run-off. The long-term effectiveness and permanence with respect to the treatment of the exposed material remaining at TP-3 is entirely dependent upon the successful design and construction of these innovative treatment systems along with the maintenance of these systems by the State of Vermont.

Preservation of Historic Site Elements. The response alternatives described in this EE/CA will all have an impact on the physical integrity of the historic landscape and resources at the Elizabeth Mine. The impacts from Alternatives 2C, 3B, 3C, and 3D will be largely indistinguishable. Alternative 2B will have a more profound impact on the physical appearance as a result of the physical removal of TP-2.

The SHPO and the community have a strong preference for alternatives that will minimize the impact on features of historic significance, including the mining landscape itself. As a result, the EE/CA has developed cleanup alternatives that minimize or eliminate construction activities near most features of historic significance, including the WW II-era buildings and the remains of buildings from early copperas and copper production.

During scoping meetings, discussions identified the attributes of the Site that are most valued by the community. They include the copperas works, the Tyson-era associated features, standing structures, Furnace Flat, the North and South open cuts, and the overall industrial landscape reflected by the tailings and waste rock piles.

The alternatives presented in the EE/CA were developed jointly by EPA, the State, and the community in an effort to evaluate alternatives that could achieve the cleanup objectives and minimize the impact of NTCRA actions on the mining landscape. None of the alternatives will have a substantial direct impact on standing structures, Furnace Flat, or the open cuts. The adverse effect for the five alternatives will be defined by the impact on the mining landscape that will alter the integrity of the setting, location of features, associations and relationships of the different mining periods and the feelings associated with the historic landscape.

EPA intends to preserve as much of TP-3 as possible and avoid direct impacts to the copperas works and Tyson-era features. The critical factor in TP-3 preservation is the amount of maintenance that the State of Vermont is willing to accept. It is not possible to anticipate the nature of the effects of the remediation upon the entire historic property until an alternative is selected and the construction proposal is in the design stage. At that point, consultation with the SHPO and the other consulting parties will continue to identify impacts and address any additional adverse effects that may be identified. The resolution of the adverse effects will be the outcome of the consultation and will be embodied in the stipulations in the MOA.

Limiting Truck Traffic. While each of the alternatives will require a large number of trucks to transport cover/cap material and other construction materials to the Site, the alternatives presented in this EE/CA vary considerably in terms of the amount of truck traffic that is likely to occur. Alternative 3B will require the largest number of truck trips (approximately 17,992), while Alternative 3C will require the fewest (approximately 3,851 truck trips). The other alternatives have a similar level of truck volume required to bring the materials to the Site. Truck traffic over town roads may be significantly reduced if local sources of common borrow material can be located and acquired. Alternative nearby sources will be evaluated in the design phase.

Scale and Cost of the Cleanups. From the beginning of EPA’s involvement, the local community has expressed concerns about the scale and cost of the cleanup. Variations in scale and cost between alternatives are largely a function of the cap/cover construction specifications. Geomembrane caps require more engineering control and construction care, whereas soil covers are generally less complex, but also potentially less effective. The current range of alternatives represent a set of options that are comparable in scale and costs and represent reasonable approaches to the environmental problems at the Site. The VTSWMR, which apply to this project, require a barrier layer over the waste. As a result only Alternatives 2B, 2C, and 3B meet the basic regulatory requirements for evaluation in terms of scale and cost.

More detailed information regarding the estimated cost of the various alternatives is included in Section 5.3. State and community acceptance and concerns regarding the scale and cost of the cleanup will be further considered following receipt of comments during the public comment period.

Innovation, Re-use, and Education: EPA believes that most of the cleanup alternatives (2B, 2C, 3B, and 3D) would include the use of innovative technologies regarding infiltration reduction. The passive treatment systems included in all of the alternatives are an emerging innovative technology. EPA agrees that re-use and education are valuable components of any cleanup. EPA has provided the community with a re-development grant to facilitate a community dialogue regarding Site re-use. EPA has been meeting with the landowners to address liability issues that could be a barrier to re-use. EPA provided a Technical Assistance Grant to the community to provide additional technical support to the community. Finally, EPA will continue to support outreach and education activities with respect to the Site.

On November 19, 2001 the EMCAG sent EPA a letter in response to the draft EE/CA. The key sections of that letter are presented below.

> *As you know, the EMCAG is committed to developing a cleanup that resolves environmental problems in a way that is sensitive to community issues –especially traffic—and protects historic resources. We applaud you for the work you have done in developing alternatives that address the issues we have raised.*
>
> *We are attaching hereto copies of comments from our technical consultants Richard Downer and Woody Reed, and will summarize our other concerns below.*
>
> ***Passive Treatment Systems***
> *As noted in his reports, Woody Reed has assured us that passive treatment systems can be designed to achieve the specified water quality goals. Considerations for the final selection of process components should include the response to our cold winter environment, costs, and maintenance requirements. We are pleased that a natural treatment system will be part of the final cleanup design.*
>
> ***Wall***
> *We support the elimination of the wall from the alternatives, provided that the alternatives can still achieve the project goals.*
>
> ***Cover System Thickness***
> *We want to minimize cleanup-related traffic impacts to our communities. Toward that end, we ask that you reduce the thickness of the cover system to the extent practicable without compromising the long-term effectiveness of the cleanup. We would also like the cover system to be designed to accommodate future use of the site. We do not yet have a collective vision regarding the future use(s) of the site, but have a consultant that will be working with the towns under a Redevelopment Initiative Grant to develop a vision for the site's future.*
>
> *We strongly support your proposal to look for onsite sources of common borrow. We also encourage you to develop a cover system that does not require large quantities of topsoil that would need to be stripped from productive farm or forest land.*

Goals of the Cleanup

Nine of our ten member groups support the goals of the cleanup, as described in the draft EE/CA. The group Citizens for a Sensible Solution (CASS) believes that the goal of designing the wetlands systems so that the receiving waters meet VT WQS is overly restrictive. CASS also believes that the cleanup should not be done under the NTCRA authority, but rather should be conducted under the Remedial process.

TP-3

Most of our member groups support the preservation of the historically significant features of TP3 to the extent practicable, provided that the cleanup goals can be met and that the State of Vermont can afford and commit to paying the associated operation and maintenance costs. We would like more information about environmental "hot spots" within TP3.

We encourage you to explore "soft" engineering approaches to erosion control to stabilize the TP3 landscape and reduce O & M costs. We suggest that part of TP3 might be used to test innovative cleanup technologies that are designed to be compatible with historic landscapes.

Operation and Maintenance Costs

Several CAG members, appreciate the ANR's statements that they intend to come up with the funding to cover future O&M costs, but believe that it is impossible to guarantee that this funding will be there forever. Therefore, they support a cleanup that minimizes future O&M.

Alternative Selection

Seven of our member organizations voiced a preference for Alternative 2B; two prefer Alternative 2, but do not have a preference between 2B and 2C; one group does not support any of the alternatives described in the draft EE/CA, and proposes limiting the NTCRA to the construction of diversion ditches and passive wetland treatment systems.

Future Use and Aesthetics

As you know, EPA has granted us money through the Redevelopment Initiative to consider future use options at the site. This initiative is in its infancy, and we ask that you leave enough flexibility in the design phase so that fairly passive land uses (such as recreation and historical and environmental interpretation) can be accommodated.

We are mindful that the physical aspects of the cleanup will be with us for generations to come. Consequently, we ask that addressing aesthetic considerations be a part of the design phase. In particular, we hope that vegetated buffers can be preserved and maintained between town roads and construction wherever possible, that staging areas be selected based in part upon their impact on viewsheds, and that the design of the drainage ditches, holding ponds and wetlands include some visual interest. "

EPA believes Alternative 2C provides a balanced approach to achieving the EMCAG concerns stated above.

5.3 Costs of Response Alternatives

The estimated cost to complete each of the response alternatives is provided in Table 5-1. The cost difference between Alternatives 2B, 2C, 3B, and 3D is within the margin of error (for cost estimation); therefore, these alternatives are essentially equal in cost.

Alternative 3C has the lowest cost of the alternatives, however, this alternative has significant concerns with respect to long-term effectiveness and is not compliant with the VTSWMR.

5.4 Differentiators Among Alternatives

In summary, the alternatives that have been described and evaluated in this EE/CA are very similar when evaluated against most of the evaluation criteria. There remain significant concerns as to whether Alternative 3C has sufficient thickness of soil to provide long-term protection against erosion and whether the thin cover would support vegetation. The major difference between the alternatives is the approach to reducing the generation of AMD from TP-1 and TP-2. Alternatives 2B and 2C offer the greatest reduction in infiltration of water and oxygen and subsequent AMD formation followed by 3D, 3B, and 3C. One critical difference between alternatives is that only Alternatives 2B, 2C, and 3B comply with the VTSWMR.

EPA has used the information and analysis contained in this EE/CA to develop a Proposed Plan (fact sheet) that will present the alternative that EPA believes is the best approach to address the contamination at the Site. This EE/CA and the Proposed Plan will be subject to a public comment period. EPA will consider the public comments and issue a decision document (Action Memorandum) along with a response to comments to formally select a cleanup alternative.

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Appendix A: Approval Memorandum

Appendix B: Engineering Support Data

Appendix C: Cost Summary Tables

Appendix D: Surface Water and Sediment Data Summaries – Select Locations

Appendix E: VTANR Memos

Appendix F: TP-1 Seep Data (ADL and USGS)

Appendix G: USGS Guidebook Papers

Appendix H: ATSDR Health Consultation Reports